POWER

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Steam

DID you ever think what a wonderful thing steam is? Its pressure lifts great weights and drives huge engines—but what makes it press? Why is its temperature 212 degrees at the pressure of the atmosphere, 350 at 150 pounds and almost 400 at 250 pounds? What is temperature, anyway?

If our eyes were sufficiently miscroscopic, we should see that none of the things about us are the continuous solid bodies that we are accustomed to regard them, but that they are composed of minute particles of matter vibrating and circulating about one another as the planets do about the sun and the moons about the planets.

It is strange to think that the impervious objects which we know and use are constituted in this discontinuous way and hold their shape simply by the mutual attraction of these myriads of particles.

When the attraction between its molecules is considerably greater than the centrifugal force due to their velocity, a mass is solid. You cannot force your finger into a block of ice because its molecules attract one another so strongly as to resist displacement

When the molecules are circling about so fast that their centrifugal force nearly equals their mutual attraction, the mass becomes liquid. You can put your finger into a bowl of water because the unbalanced attraction is not enough to resist its pressure. There is still some attraction. It holds the molecules together in the drop that depends from your finger or in the globule of dew upon a blade of grass.

To change the substance from a solid to a liquid, its temperature was raised, which means that the velocity of its molecules was increased. If the temperature is raised still further—that is, if the velocity and thus the centrifugal force of the molecules is increased—there will come a time when the attractive force will be completely overcome and the molecules will fly off like stones from a slingshot.

It is the impact of these projected molecules upon the containing surfaces that produces pressure.

These swiftly moving little projectiles strike the steel walls that retain them and are projected back with the same velocity. The steel wall is, itself, a discontinuous structure, an openwork of planetary systems. The steam molecule does not strike it and rebound by impact like a billiard ball striking a solid surface. It meets a lot of molecules circulating about with an energy equal to its own, for their temperature is the same, and is whirled around and turned back like the dancer in a lancers.

Notwithstanding the molecules in the steel are already separated by distances many times their diameter, it takes a force of fifty or sixty thousand pounds to pull as many of them as are in a square inch of surface out of the range of each other's attraction. The struggle that goes on between the bombardment of these tiny projectiles and the cohesive force of the plate is a veritable battle of the molecules.

The temperature at which water will boil depends upon the pressure that it is under, because the centrifugal force of its molecules due to their velocity, that is, to their temperature, has to be sufficient to overcome not only their attraction for one another, but to batter back the wall of water that surrounds them, and the greater the pressure of this water the greater the centrifugal force required to overcome it. Steam of high pressure exerts its greater force because of its greater density. There are more molecules in a cubic foot of it and a correspondingly greater number of impacts per second on the walls of the container. As its pressure is increased, a point is reached when its density becomes equal to that of the water from which it was made. The steam is as thick and heavy as the water. This is the "critical point" somewhat less than 700 degrees and about 3,000 pounds.

Surely, steam is a wonderful thing; but some men make it and work with it all their lives and never think of it as more than fog.

A Modern Power Plant in the Rubber-Tire Industry

DURING 1916 the Kelly-Springfield Tire Co. decided to construct a model tire factory, especially designed for the most efficient and economical production. Cumberland, Md., was chosen as an ideal location for the new plant, and ground was broken in 1917, but war conditions made progress slow. The first plant unit, the mechanical building, was finished in 1918. The intake building and the pumphouse were completed during 1919, while the boiler house and other buildings were finished in 1920.

THE Cumberland Plant of the Kelly-Springfield Tire Company follows approved engineering practices with coal-handling equipment, water-tube boilers, superheaters, steam turbines, air-compressors and hydraulic pumps.

The power-generating plant consists of a boiler house containing six 7,406-sq.ft. boilers, equipped with stokers and superheaters, feed-water heaters, boiler-feed pumps and other accessories and the generating room which contains two 5,000-kva. Curtis alternating-current 2,300-volt three-phase 60 cycle turbo-generator sets for power generation. The excitation is secured from a 100-kva. motor-generator set and a 300-kva. turbo-driven generator, which latter unit is also used for night-lighting service. Two 1,000-kva. motor-generator sets are also installed in this building to supply the direct current necessary in the manufacturing departments. The pumping equipment, consisting of pumping engine, fire pumps, hydraulic pressure pumps, compressors, etc., is located in a pumphouse close to the river.

Coal is received in standard drop-bottom cars and dumped directly into the coal basin (Fig. 2) which is of concrete construction and has a capacity of 7,000 tons. The bottom of the coal-receiving basin is some distance below the normal water level of the Potomac River, and the basin is so connected with the river that coal may be stored either under water or dry, as desired. The connection to the river is controlled by sluice gates and valves, which make it permissible for water to enter from the river or drain from the coal basin into the river.

The coal is handled from this basin by a locomotive crane equipped with a clamshell bucket into a traveling coal crusher. The crusher in turn discharges through slots in the coal-tunnel roof onto the conveyor belt within the tunnel. This belt delivers coal to an elevator

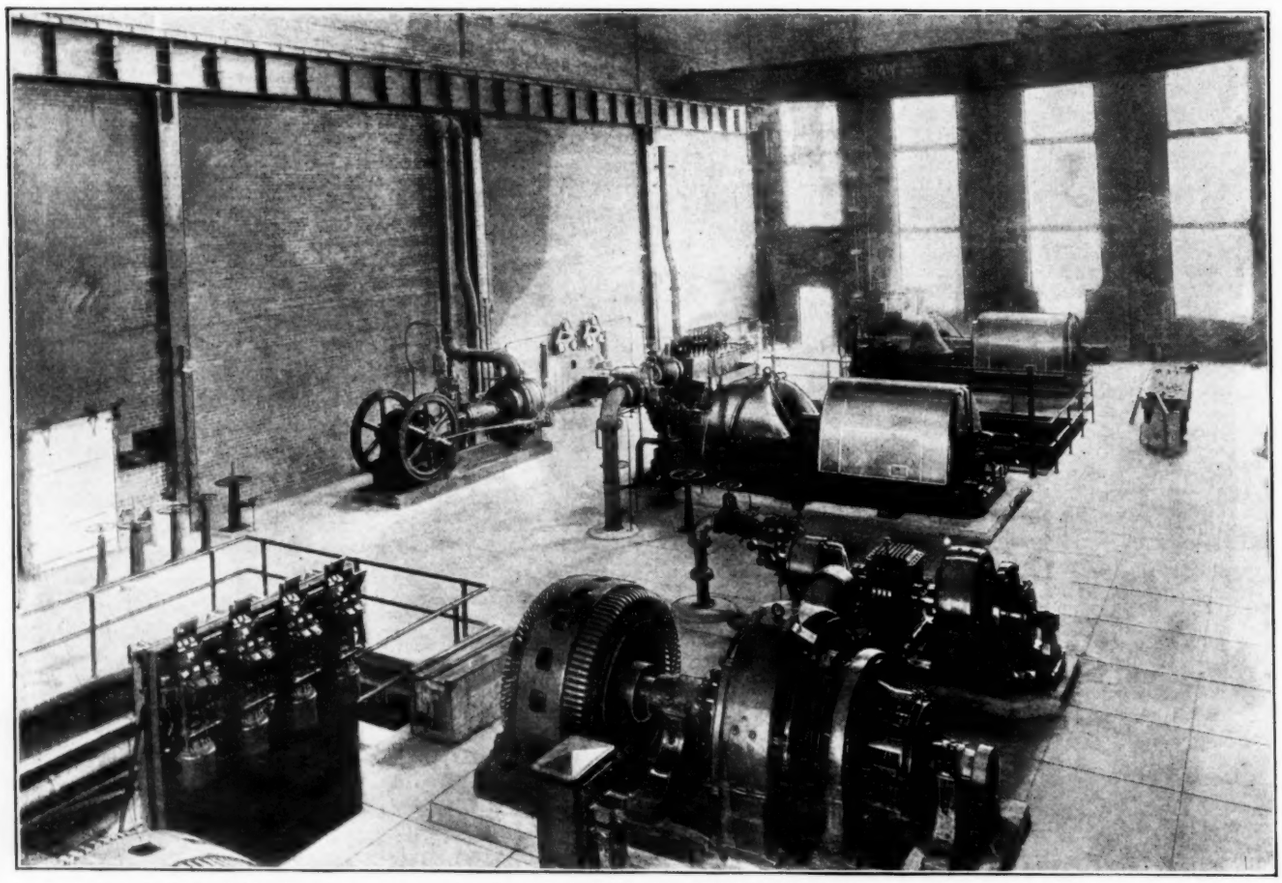


FIG. 1. TURBINE ROOM SHOWING TWO 5,000-KVA. TURBO-GENERATORS, MOTOR-GENERATOR SETS, TURBO-EXCITER AND VACUUM PUMP

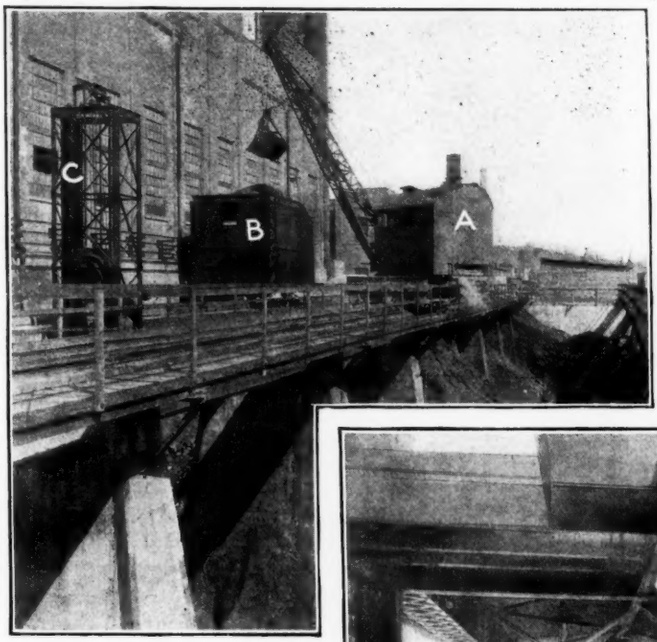


FIG. 2. COAL BASIN AND CRANE

The locomotive crane *A* handles the coal from the basin to the crusher *B*. After crushing, the coal is dropped into a conveyor tunnel which delivers it to the boot of elevator *C*. The elevator delivers the coal into hopper *A* in Fig. 3.

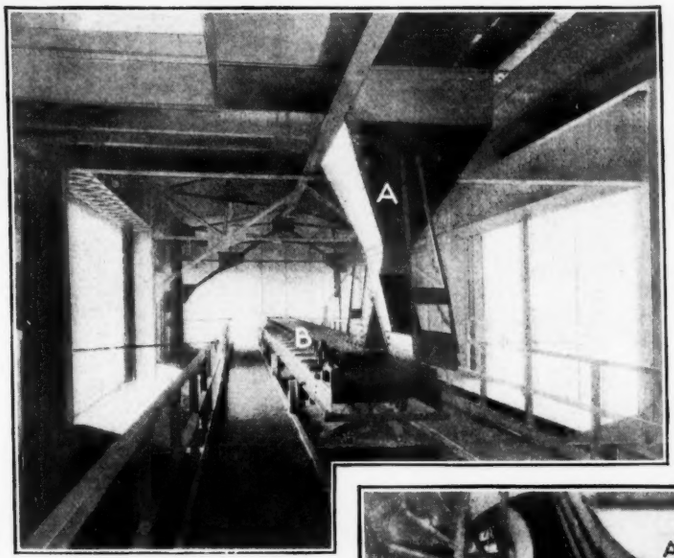


FIG. 3. DISTRIBUTING CONVEYOR

The crushed coal is delivered from the elevator *C*, Fig. 2, into the hopper *A*, which deposits it upon the conveyor belt *B*. The belt is mounted on a shuttle truck enabling the fuel to be dropped into any of the bunkers *A* shown in Fig. 4.

which conveys it to overhead coal bunkers above the center aisle of the boiler room.

Fig. 2 is a general view of the coal basin, crane and crusher. The coal crusher, as well as the truck on which it is mounted, is electrically driven. This arrangement makes it possible to handle coal from the basin to the crusher with the utmost speed, since the crusher can at all times maintain its relative distance from the locomotive crane. The coal tunnel which receives the coal coming from the crusher has a continuous slot in its roof and extends the full length of the boiler house. The pit containing the coal elevator boot and hopper into which the conveyor belt discharges the coal is located along this tunnel. An emergency, collapsing elevator is provided in the coal basin immediately adjacent to this receiving hopper, so that in event of breakdown, slack or crushed coal may be conveyed directly from the coal basin to the bunker conveyor.

The overhead coal bunker is of steel construction with concrete-closed steel bracing members. A shuttle conveyor delivers the coal into any desired bunker. Fig. 3 shows the conveyor over a bunker. Aside from the locomotive crane all this coal-handling equipment is motor-driven. The electric control for the several motors is all interlocked in such a manner that breakdown or stoppage of any of the drives will automatically stop the entire coal-handling system, thereby avoiding damage through jamming.

From the bunker the coal passes to each stoker receiving hopper through two 12-in. pipe chutes equipped with weigh meter and a chain-operated gate at the hopper end.

The boilers, which are steel-cased, are equipped with inclined stokers with individual drive, and no lineshaft, belt or chain drives are used in any part of the stoker installation. A cross-section view of one of the boilers with stokers is shown in Fig. 5. The coal siftings passing through the stoker are dropped into hoppers below the air-blast chambers and are from time to time removed by being discharged into ash cars in the tunnel running underneath the boiler furnace, and are then returned to the coal supply at the elevator booth.

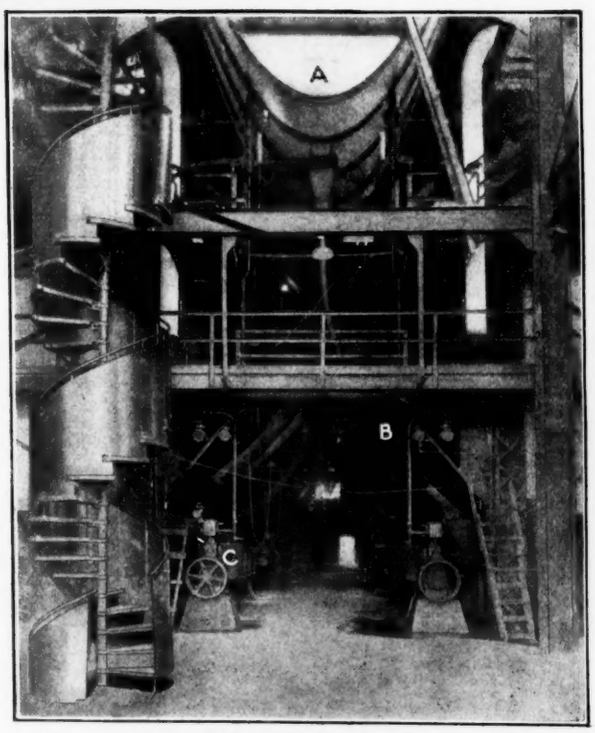


FIG. 4. BOILER ROOM, SHOWING COAL BUNKERS *A* AND CHUTES *B* WHICH CARRY THE COAL TO THE STOKERS

The boiler ashes drop into firebrick-lined cast-iron hoppers below the floor level, the hoppers having a capacity sufficient for two days' operation. The ashes

are removed from the hoppers by specially designed water-sealed hydraulically operated gates (illustrated in Fig. 7) and discharged into electric storage battery cars which convey them to the 600-cu.yd. storage pit at the end of the coal-storage basin. The fly ash from the

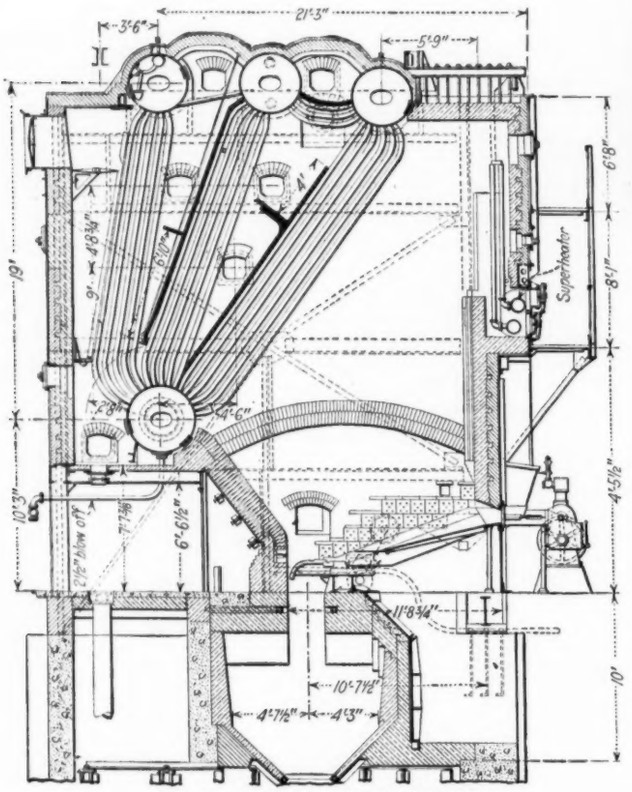


FIG. 5. BOILER CROSS-SECTION

rear pass of the boiler is removed by periodically discharging it through pipes into ash cars in the basement.

Boiler settings are entirely of special design, the steelwork being incorporated with that of building proper, and were designed by the Kelly-Springfield Tire Co.'s engineers, drums and tubes only being furnished by the boiler manufacturer. Silocel was used for insulating purposes between the steel casing and brick lining while non-clinking furnace blocks were used in the furnaces. The flat arches over the combustion chambers are of special patented design.

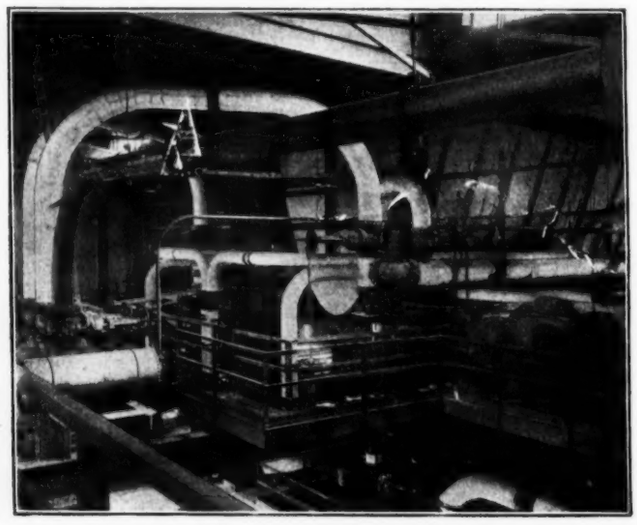


FIG. 6. VIEW OF BOILER-ROOM GALLERY, SHOWING PIPE ARRANGEMENTS

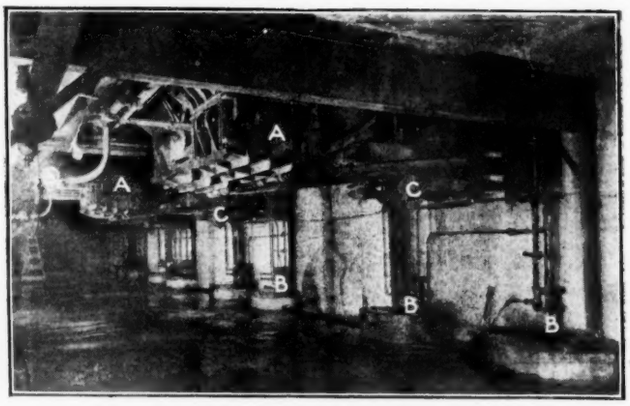


FIG. 7. BOILER ASH-HOPPER GATES

The ash gates *AA* are operated by hydraulic pressure. The valves *B* control the water flow to the hydraulic cylinders. The fly-ash gates are shown at *C*.

The location of the superheater in the front wall (Fig. 3) is unusual. Since on heavy ratings the decreased efficiency requires more coal per pound of steam, the gas velocity increase is above the increase in steam supply. The higher heat transmission causes a greater superheat. If the coils are out of the path of the gases, only radiant heat is absorbed, and since this is more uniform than the gas velocity, the superheat is kept nearer constant.

Boiler-feed pump capacity has been provided in liberal excess, there being two 18 x 30 x 16 x 24 steam pumps installed in a projecting wing of the boiler house. This wing also contains the pumps for operation of the water-sealed dump gates of the boiler ash-hoppers. Feed water is heated by exhaust steam from boiler- and pump-house auxiliaries in connection with a feed-water heater, and is metered so that accurate records may be secured.

Brick-lined, steel-plate breechings connect the boilers to the two radial-brick stacks, each 14 ft. inside diameter at top, and 250 ft. in height above the boiler-room floor level. Each stack rests on a concrete foundation, about 40 ft. in diameter which is tunneled in order that the ash tunnels under the boilers may continue in a straight line in the event that the boiler house is extended in the future. Ash accumulation in the stacks is removed by opening gates at the bottom of the stack hoppers and permitting the dust to drop into the ash cars which convey it to the ash waste pit.

Forced draft for boilers is provided by turbine-driven steel-plate fans (Fig. 8) of sufficient capacity to take care of double the present installation when working at 200 per cent of rating. The forced draft is conducted through a concrete passage with damper connection at each boiler and so arranged and equipped with air locks that inspection may be made at any time by entering this duct while it is under pressure. Through this provision blast gates may be repaired or replaced without shutting off the draft from the chamber or in any manner interfering with the full operation of such boilers as may be in service.

Steam for operating the turbo-generator sets and the different pumping units leaves the boiler house at 175 lb. pressure and 100 deg. superheat, the loop system of piping being so arranged that superheated steam can be turned into saturated mains, or vice versa, if so desired. Boilers are equipped with such accessories as are necessary to secure proper control and economical operation.

There is ample storage space for tubes and refractories in the boiler-house basement. Office, toilet and locker rooms are provided for the employees. Shower baths are also provided, and every attention has been given to the comfort, safety and general welfare of those engaged in and about the entire plant.

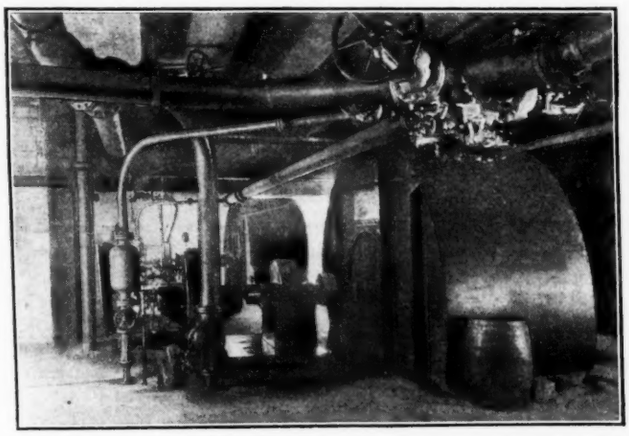


FIG. 8. FURNACE DRAFT FANS

Each 10-ft. 6-in. steel-plate fan is driven by a steam turbine through reduction gearing. These fans are located in boiler room basement.

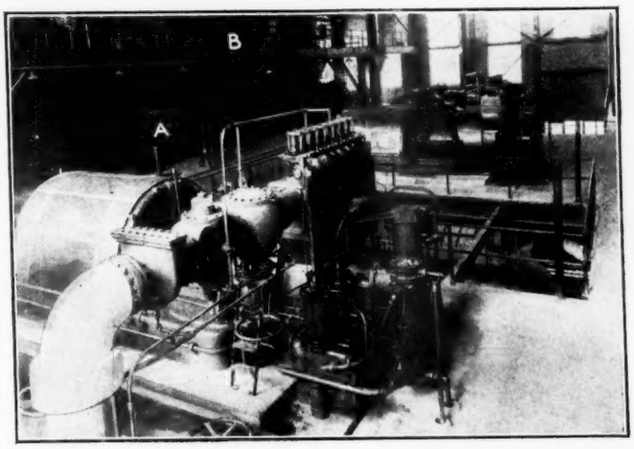


FIG. 9. VIEW OF TURBINE ROOM

The switchboard is located at *A*, while the oil switches and other electrical devices are placed on the gallery at *B*.

The water-intake house is located on the river bank. The building is of brick and steel construction with concrete roof. All water, other than for drinking purposes, enters through four screen-guarded concrete chambers in this building and, after passing through moving screens of fine mesh, enters the main water tunnel and continues over to the power house. A branch tunnel is taken off to supply the suction pit in the pumphouse, no piping whatever being used between the river and the suction pits of the various pump installations. The intake house is about 42 ft. by 42 ft. and, with the river at its lowest stage and with water entering at very low velocity, has intake capacity in excess of the normal flow of the Potomac River at that point. This building is equipped with an overhead traveling crane to facilitate the raising of screens for inspection and repairs.

The turbo-generator units are all provided with quick-stop valves which can be tripped from remote points if desired. The motor-generator sets take care of the three-wire 115-230 direct-current system for variable-speed motor drives.

Condensing equipment for the two 5,000-kw. units which, with the exception of the vacuum pump is located in the basement, consists of two large surface condensers with their circulating pumps, condensate pumps and rotative dry vacuum pumps.

The circulating pumps take their water from the water tunnel below the power-house floor, and after passing through condensers, the water is discharged into the tunnel under the basement floor at the rear of the condensers. All condenser auxiliaries are cross-connected so that they can be utilized on either or both condensers. Fig. 10 illustrates the connection at the circulating pumps. The condenser hotwells are provided with high-water alarms and at the same time with devices that will automatically shut down the vacuum pumps in the event of excessive water, before any damage can be done to the pump.

The main switchboard will be seen in the background in Fig. 9 on the main floor at *A*. The balcony *B* contains the switches and rheostats, all of which are solenoid operated from the switchboard below. This installation is illustrated by Figs. 11 and 12. Breaker panels for the motor-generator sets are located advantageously immediately to the left of the units, and the equalizer switches are on pedestals adjacent to the motor-generators. Voltage regulators are located on their own pedestals, adjacent to the main switchboard. All conductors within the power house and extending over to the switching station in the main factory building are of bare copper, so placed as to be properly safeguarded.

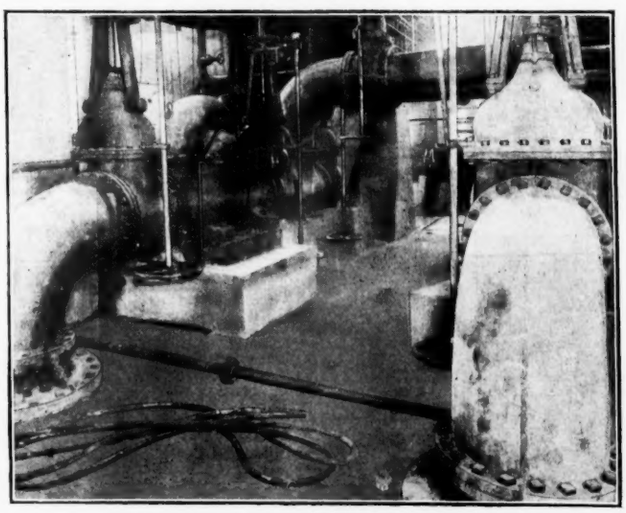


FIG. 10. CONDENSER CIRCULATING PUMP IN BASEMENT

The two 1,000-kw. motor-generator sets already mentioned, are set on concrete foundations which extend

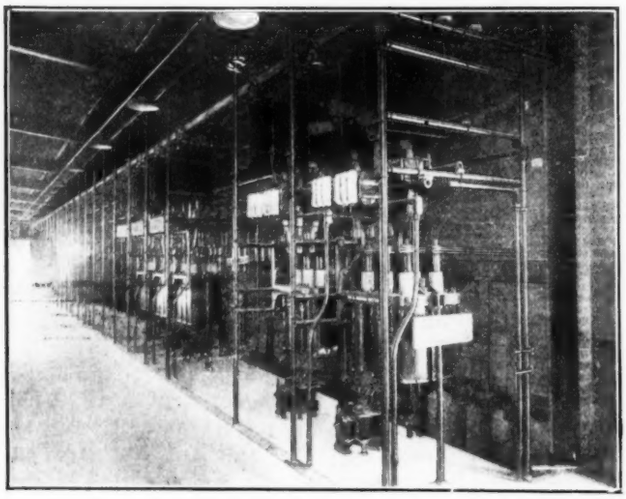


FIG. 11. OIL SWITCHES

The oil switches shown at upper left are located on a gallery above the switchboard. The switches are electrically controlled from the board below.

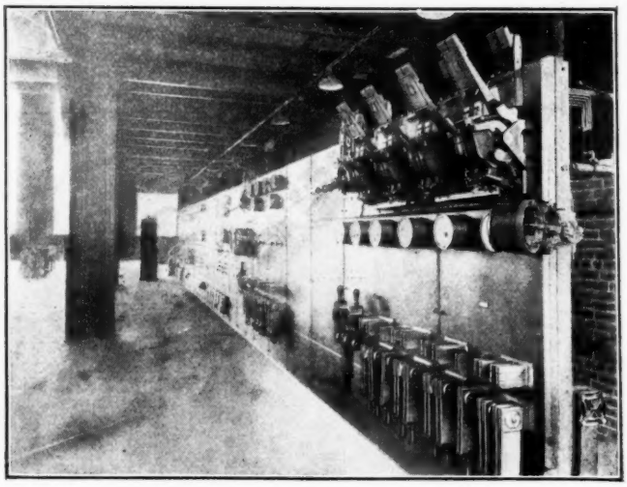


FIG. 12. CLOSE-UP VIEW OF SWITCHBOARD

The switchboard at upper right is placed lengthwise of the turbine room with the instruments in plain view of the operators.

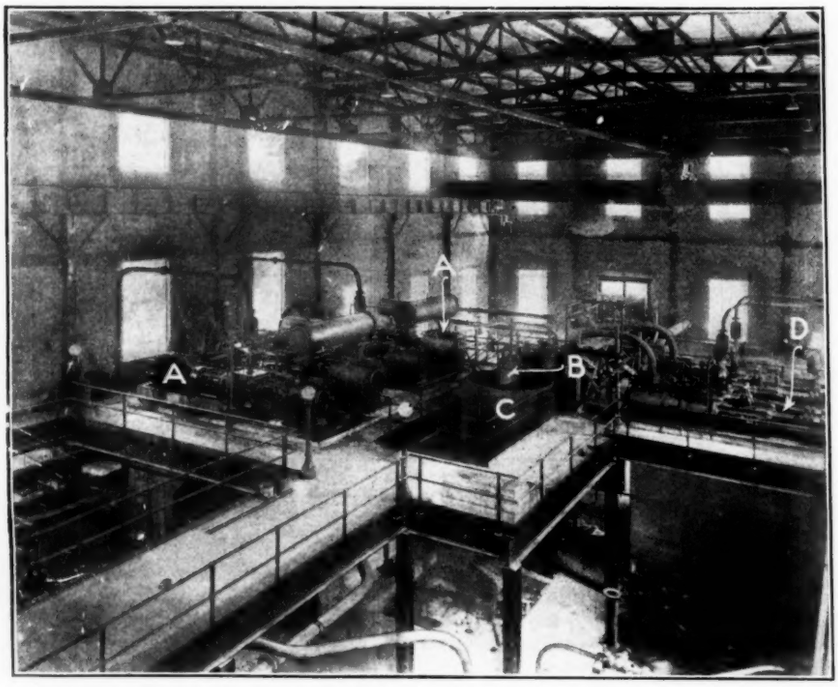


FIG. 13. PUMPHOUSE MACHINERY

The two air compressors are shown at *A*, *A*. The hydraulic pressure pumps *D*, *D* are served by the ram accumulator *C* and *B*. These units are on the main floor. A traveling crane shown in the illustration serves both the machinery on the main floor and the pumps located in the basement which are reached through the floor openings.

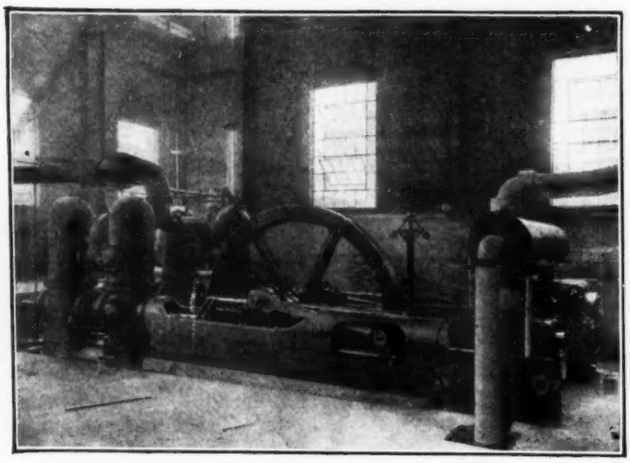


FIG. 14. COMPOUND CORLISS PUMPING ENGINE IN BASEMENT OF PUMPHOUSE

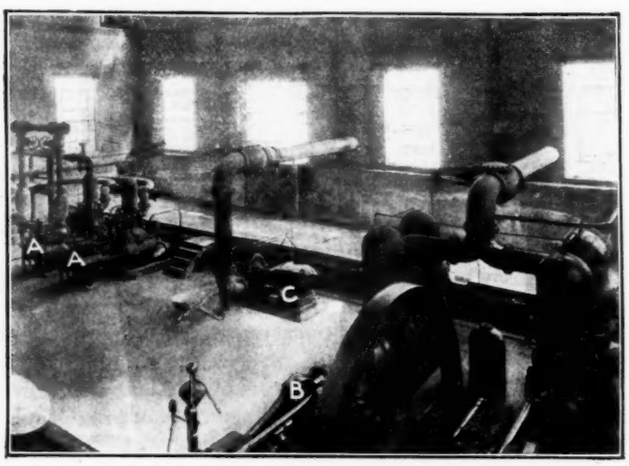


FIG. 15. FIRE-SERVICE AND EMERGENCY PUMPS IN PUMPHOUSE BASEMENT

DATA ON PRINCIPAL EQUIPMENT IN THE CUMBERLAND, MARYLAND PLANT OF THE KELLY-SPRINGFIELD TIRE COMPANY

Plant location	Cumberland, Maryland
Character of service	Industrial power
Capacity	10,000 kw.
Type of buildings	Brick and Steel
Consulting engineers	S. Diescher & Sons
Turbine-room dimensions:	
Inside width	71 ft. 4 in.
Inside length	135 ft. 0 in.
Crane span	54 ft. 4 in.
Basement floor to main floor	18 ft. 0 in.
Main floor to truss chord clearance	37 ft. 6 in.
Boiler room dimensions:	
Inside width	99 ft. 6 in.
Inside length	135 ft. 0 in.
Main floor to truss chord clearance	52 ft. 3 in.
Basement floor to main floor	21 ft. 6 in.
Heater wing, inside width	39 ft. 0 in.
Heater wing, inside length	35 ft. 0 in.
Width of alleyways between boilers	9 ft. 6 in.
Width of firing aisle between boiler fronts	21 ft. 0 in.
Width of passageway behind boilers	12 ft. 6 in.

BOILERS AND SUPERHEATERS

Make of boilers	Babcock & Wilcox
Type	Stirling vertical water tube
Number (ultimate)	8
Number (installed)	6
Water-heating surface per boiler, sq.ft.	7,406
Grate area per boiler, sq.ft.	144.5
Ratio water-heating surface to grate surface	51.25
Heating surface per kilowatt installed (excluding pumping engines)	4.44
Heating surface per sq.ft. boiler-floor area, sq.ft.	3.3
Cubic feet boiler room per sq.ft. boiler-heating surface	19.42
Furnace volume per boiler, cu.ft.	3,650
Ratio furnace volume to heating surface	0.49
Ratio furnace volume to grate surface	25.2
Size of tubes, in., dia.	3¼
Number of tubes per boiler	568
Steam drums, size	42 in. by 17 ft. 5 in.
Number of passes	3
Boiler pressure, lb. per sq.in. gage	175
Make of superheater	Foster
Degree of superheat at 200 per cent rating, deg. F.	100
Total steam temperature at 200 per cent rating, deg. F.	477.6
Type of setting (designed by S. Drescher & Sons)	Steel casing

STOKERS

Make	Sanford Riley
Type	Underfeed
Number of retorts, each	8
Drive	5 x 6 Sturtevant engines
Draft	Two 10 ft. 6 in. Sturtevant plate fans geared to Sturtevant E-6 Turbines
Draft Duct, sq.ft. cross-section	120

CHIMNEYS

Number	2
Type	Radial brick
Make	Alphons Custodis Co
Height, ft.	250
Inside diameter at top, ft.	14
Wall thickness at base, in.	32
Wall thickness at top, in.	8
Depth of foundation, ft.	42
Foundation area, sq.ft.	1,580

COAL BUNKERS

Type	Concrete suspension
Make	Brown Hoisting Mchry.
Diameter of chutes, in.	12
Capacity of bunkers, total tons	600
Capacity per lineal foot, tons	5.75

COAL HANDLING EQUIPMENT

Coal storage capacity, tons	7,000
Crane	Locomotive type
Make	Browning
Clamshell buckets, make	Blaw-Knox
Crusher, type	Traveling
Capacity, tons per hour	125
Make	Heyl & Patterson
Drive	Electric motor
Horsepower	75
Coal conveyor system, type	Belt
Make	Link-Belt Co.
Bucket elevators	119 ft. double strand 18 in. pitch double roller chain driven by 35 hp. motor.
Make of elevator	Link-Belt Co.
Horsepower of overhead belt conveyor	7½
Horsepower of shuttle belt conveyor	10
Horsepower of shuttle belt truck	5
Emergency elevator from coal pocket to receiving hopper, capacity hourly	20 tons
Make	C. P. Bartlett & Snow
Drive	5 hp. motor

ASH HANDLING EQUIPMENT

Type	Electric cars
Drive	Storage battery
Make	Elwell-Parker Elec. Co.
Disposal	Railway cars
Type ash gate	Hydraulic operated
Make	Gillespie Mfg. Co.

BOILER FEED

Source	Turbine condensate
Feed pumps, duplex	18 x 30 x 16 x 24
Make	Epping-Carpenter
Number	2
Feed water heater:	
Type	Open, class H
Make	Hoppes
Number	1
Capacity, cu.ft. water	285
Square feet heating surface	1,300

PRIME MOVERS

Type	Curtis turbine
Make	General Electric Co.
Number	2
Capacity, rated kw.	10,000
Speed, r.p.m.	3,600
Number of exciters	2
Drive	One 100-kw. motor generator exciter and one 300-kw. turbo-generator exciter
Ratio of exciter to generator capacity	1 to 25
Motor-generator sets	2
Capacity each, kw.	1,000

CONDENSERS

Type	Surface
Make	Wheeler Condenser & Engineering Co.
Number	2
Square feet tube surface	10,000
Sq.ft. tube surface per kw. of prime mover	1
Circulating pump	20 in. Centrifugal
Make	Wheeler Condenser & Engineering Co.
Drive	Terry Turbine
Capacity, gal. per min.	10,000
Dry Vacuum pump	Tandem rotative
Make	Wheeler Condenser & Engineering Co.
Size	12 x 30 x 18
Drive	Direct acting
Hotwell pump	5-in. centrifugal
Make	Wheeler Condenser & Engineering Co.
Drive	Geared to 15-hp. Terry Turbine

PUMPHOUSE EQUIPMENT

Pumping engine	1
Type	Duplex outside packed direct connected to compound Corliss engine.
Make	Allis-Chalmers
Capacity, gal. per day	6,000,000
Service	Water supply
Emergency pump	1
Type	Single-stage centrifugal
Make	Allis-Chalmers
Capacity, gal. per min.	4,000
Head, ft.	140
Drive	Direct-connected to motor
Service	Emergency water supply
Fire pumps	2
Type	Steam driven duplex piston
Make	Worthington Pump & Machinery Corp.
Size	20 x 12 x 16
Capacity, gal. per min. each	1,500
Hydraulic pumps	2
Type	Duplex
Make	Worthington Pump & Machinery Corp.
Size	18 x 30 x 5 x 24
Service	Hydraulic presses, etc.
Accumulators	2
Size	12 in. ram x 12 ft. stroke
Make	Wellman, Seaver, Morgan Co.
Hydraulic pump, low-pressure	
Type	Compound steam-driven duplex
Size	14 x 20 x 10 x 16
Boiler feed pumps	2
Make	Worthington Pump & Machinery Corp.
Type	Steam compound-driven duplex
Size	18 x 30 x 16 x 24
Air compressors	2
Type	Direct connected compound steam and compound air cylinders
Size	15 x 27 x 27 x 15½ x 24
Make	Worthington Pump & Machinery Corp.
After cooler	1
Size	500 sq.ft. steel tube
Make	Worthington Pump & Machinery Corp.

PUMPHOUSE ACCESSORIES

Twin strainers for hydraulic return tanks	Elliott Co.
Air tank 60 in. dia. x 11 ft. 6 in. long	Quaker City Iron Works
Pipe and fittings	Crane Co.
Pipe erection	Riggs, Distler & Stringer
Wiring	Riggs, Distler & Stringer
Plumbing	Weldon & Kelly Co.
Governors for boiler-feed pumps	Chaplin-Fulton Mfg. Co.
1 Shaw 20-ton crane	Manning, Maxwell & Moore

STANDPIPE

25 ft. dia. x 115 ft. high standpipe	Jas. McNeil & Bro. Co.
Spiral stairway for standpipe	Taylor & Dean

BOILER AND POWER-HOUSE ACCESSORIES

Fabricated steel for boilers	McClintic-Marshall Con. Co.
Boiler settings	George Allen & Sons
Sil-o-cel Insulation	Celite Products Co.
Furnace Blocks	Drake Furnace Block Co.
Indicating draft gauges	Precision Instrument Co.
Foster superheaters	Power Specialty Company
Soot cleaners	Diamond Power Specialty Co.
Valves for soot cleaners	Edwards Valve and Mfg. Co.
Boiler-feed controls	Williams Gauge Co.
Recording thermometers for feed-water	The Foxboro Co.
Ashton Master Pilot pressure gauges	Ashton Valve Co.
Simplex Venturi-Tube Water Meters	Simplex Valve & Meter Co.
Steam meters	Bailey Meter Co.
Combustion Control	The Hagan Corporation
Safety valves	Consolidated Safety Valve Co.
Water columns	Williams Gauge Co.
Steam gages	Star Brass Mfg. Co.
Blowoff valves	Edwards Valve and Mfg. Co.
Stop valves	Locke Regulator Co.
Ash hoppers	Gillespie Mfg. Co.
Pump for ash gates	Worthington
Tank Governor	Chaplin-Fulton Co.
Hydraulic four-way valves	Vance-Vetter Co.
Globe anld angle valves	Jenkins Bros.
Motor-generator, battery charging	Frank B. Ward Co.

below the basement floor and are cored out, thus affording chambers for the transformers, etc.

Steam, water, air and all other pipes, with the exception of the yard fire lines, are carried throughout the plant in large tunnels, there being no piping buried in this installation other than the outdoor fire lines leading to hose plugs in yard.

Pumphouse Equipment

The interior of the pumphouse is shown in Figs. 13, 14 and 15. The pumping engine (Fig. 14) and the emergency centrifugal pump *C* and the fire pumps (*A*, Fig. 15) are on the lower floor level, while the remainder of the equipment is on the upper level, all accessible to the overhead traveling crane of 20-ton capacity. Ample space is provided for more than double the present equipment without extension to building. Water is conducted to the pumphouse through an underground tunnel about 50 sq.ft. in cross-sectional area, joining with the power-house water tunnel a short distance from the intake house. Adjacent to this connecting point sluice gate chambers are provided so as to afford full control, or shut off, for cleaning tunnels, extension, etc. Water enters the pumphouse suction pit through vertical traveling screens, of fine mesh into the suction pit, which extends entirely across the pumphouse. This pit has side walls extending to a sufficient height above the basement floor to afford protection against high stage of water in the river, and it is covered with a grating floor and has a depth equal to the elevation of the river bottom.

Drawing from the suction pit, at present, there is one compound condensing pumping engine of 6,000,000 gal. daily capacity, with space provided for a second similar unit; a motor-driven centrifugal pump for emergency use, of about 4,000,000 gal. capacity, and two Underwriters' fire pumps, each of 1,500 gal. per min. capacity. Service and centrifugal pumps both deliver their output to a 25 x 115-ft. standpipe in the yard adjacent to the pumphouse. Drinking water, at present, is taken from the city water mains and is piped in such a manner that a refrigerating unit may be connected thereto at a later date.

For high-pressure hydraulic service of 2,000 pounds, two 18 x 30 x 5′ x 24-in compound steam-driven duplex pumps (*D*, Fig. 13) are provided. These are on the main floor of the pumphouse, while the accumulators *B* and *C* extend from the basement floor to the main-floor level. Two low-pressure pumps, 14 x 20 x 10 x 16-in. for 300 lb. pressure are also placed on the main floor. The upper level also contains, at present, two 15 x 27 x 27 x 15½ x 24-in. air compressors (shown at *AA* Fig. 13) with the usual aftercoolers, air tanks, etc.

Water Pumps Available for Fire Fighting

All water pumps, with the exception of boiler-feed and high-pressure hydraulic pumps, are so connected that they may be utilized for fire fighting as well as for plant service. All discharge piping from the various fire pumps, service pumps and city water are bypassed, in the basement of the pumphouse, at a common point, thereby placing control for fire-fighting purposes at a convenient point.

The piping material included numerous special fittings, with supporting legs to rest on concrete piers, or with flanges for attachment to steelwork, where otherwise several standard fittings combined would have been necessary to accomplish the same results. Condensation, accumulated at separators, water legs and drips, is returned to the boilers by a gravity return system.

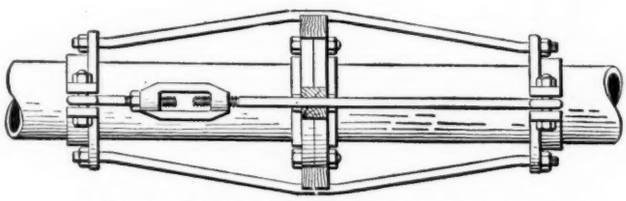
Piping in this plant includes high- and low-pressure lines for steam, service water, water for fire protection, hydraulic lines of 300 lb. and 2,000 lb. pressure, compressed-air lines and low-pressure heating lines. The maze of pipe and cable often found in basements of industrial plants is avoided by placing all lines in tunnels and in trenches below the basement floor, extending the full length of the main building and covered with floor plates. With this arrangement leakage or water from breaks in the piping will drain through the trenches, and the floor plates give ready access for repairs. All high-pressure hydraulic lines are safeguarded at strategic points by the installation of hydraulic relief valves and shock absorbers.

Bridling a Flanged Union To Prevent Leakage

By A. J. Dixon

A 4-in. pipe conveying steam for certain manufacturing processes, drops about 35 ft. from the main header in an engine room to a tunnel underneath the floor, where it connects with a horizontal run of pipe. There is an offset of about 3 ft., made with 45-deg. elbows, in the descending section of the line and a flanged union about the middle of the drop.

Owing to the vibration of the pipe the union was constantly giving trouble on account of leakage through



THIS BRIDLE RELIEVED PIPE THREADS OF VIBRATION STRESSES

the threaded joints, although the joints with gaskets remained tight. The union had to be uncoupled frequently, and the flanges removed and replaced with new ones.

To prevent this localization of the vibratory effect, the engineer devised a bridle, shown in the sketch, for holding rigid the flanges and pipe ends. A pair of clamps, made of ½ x 2½-in. flat iron, with lugs welded on as shown, grip the pipe on each side of the union. Four ¾-in. tie rods are used. Two of these are drawn taut by means of turnbuckles, and the other two by means of the nuts on their ends. Wooden blocks are interposed between the edges of the flanges and the tierods.

The action of sulphuric acid on wood is to extract the moisture from it and thus cause charring or carbonizing, quite as if burned. The charred part is a conductor of electricity so that this action is undesirable in storage batteries. As long as the wood is submerged in the electrolyte and plenty of moisture is available, this effect does not occur to any great degree, but if allowed to dry out it will take place. After once being wet with electrolyte, the wood separators in storage batteries must be kept moist.

Electrical Equipment of Hydro-Electric Plants

Types of Generators and Exciters Employed—Simple Outline of Their Construction and Operation—Conditions Imposed by Character of Load—Voltage Regulation—Operating Hints for the Engineer

By N. L. DEVENDORF
Instruction Department, Consumers Power Company

A HYDRAULIC turbine may be employed to drive any sort of machinery by direct connection, gear, belt or rope drive, or by the combination of any or all of these. Direct mechanical connection to the load is widely used, but it is being supplanted by electric drive, whereby not only great economies in the individual installation may be effected, but many diversified processes at widely separated points may be carried on with power from a single installation, or a number of installations operated in parallel with increased efficiency over the individual mechanical drive.

In the isolated plant of the average factory the losses in shafting, belts and other parts of the mechanical drive often amount to a large percentage of the power of the turbines. Mechanical transmission for any distance is out of the question. Wire ropes and compressed air have been used in the past for the operation of machinery a short distance beyond the range of lineshafting, but these have been largely superseded by the highly efficient electric generator, motor, transformer, and transmission line, by which the energy losses between prime mover and load are reduced to a minimum.

This is as true of the transmission system covering one-half of a state as it is of the individual factory power plant. The high potential transformer and transmission line have made available remote water powers that would otherwise have little or no economic value. Such power can be transmitted electrically three or four hundred miles, often with a smaller percentage of loss than is found in some types of gear and shafting transmission for as many feet.

Construction of Hydro-Electric Generators

Nearly all generators in use in hydro-electric plants are of the alternating-current, synchronous, revolving-field type. The stationary armature consists of a core of sheet-steel stampings clamped in a circular cast-iron frame, slots being cut in the inside periphery of the core sheets in which the armature windings are embedded, and from which they are highly insulated. This is known as the "stator" of the machine.

The rotating field, or "rotor," consists of copper coils surrounding the magnetic polepieces, which are mounted on the cast-iron or steel rim of a large wheel, or "spider." The polepieces are built up of laminated sheet-steel stampings which, for moderate speeds, are riveted or bolted together, the whole being solidly bolted to the rim. For higher speeds the poles are attached to the spider by dovetailed joints. The field must be made strong mechanically to withstand not only the centrifugal force due to the normal speed of the unit, but also that developed in case the turbine should run away, when it is likely to attain double its normal speed.

In the modern generator the field windings are of copper strip wound on edge and insulated with paper, asbestos and varnish. This type of winding is preferable to wire, as it will better withstand the centrifugal stresses and is more satisfactory for the radiation of the heat due to the field current.

As the synchronous generator is not self-exciting, the excitation of the field is supplied from an external source of direct current, usually from a small direct-current generator connected to and driven by the unit, the generator field of which it excites. This machine is known as the exciter.

Usually, the generator rotor is direct-connected to its hydraulic turbine except in the case of some of the older small plants, where the gear, belt or rope drive is still in use. The number of field poles is that required to obtain rated frequency at the normal speed of the turbine, which is determined by the head and the type of the runner. As the frequency is equal to the speed in revolutions per second multiplied by the number of pairs of poles, it will be evident that the slower the speed the greater is the number of poles required to obtain the rated frequency and, consequently, the size and cost of the generator.

Bearings and Lubrication

In the horizontal generator the bearings are of the babbitted, oil-ring type, supported on pedestals which, with the armature frame, rest on a heavy cast-iron base, and this in turn is set on a concrete foundation. The oil rings hang freely on the shaft and dip into oil contained in a reservoir in the pedestal. As they revolve with the shaft, sufficient oil for continuous lubrication adheres to the rings and is carried up to the shaft, where it spreads out to all parts of the bearing through oil grooves cut in the babbitt, wedging in between shaft and bearing and by reason of its viscosity clinging to the metal so that the surfaces are kept separate, and the actual friction is that due to the particles of oil rolling on one another, which is much less than the friction of metal to metal. This is the principle of all bearing lubrication. The steel shaft and the babbitt bearing are never in actual contact except at the instant of starting, as the oil film cannot form until there is motion to draw it in between the bearing surfaces.

In the vertical type of generator the entire weight of the rotor, including the turbine runner, shaft, spider, field poles and, where it is direct-connected, the exciter armature, is carried on a single-thrust bearing mounted on the top of the generator frame. This thrust bearing is an important and interesting part of the vertical unit. It consists essentially of a runner or ring attached to the shaft collar and rotating with it. This runner slides on a stationary ring or shoes, solidly supported under it. In one type the stationary element is a steel ring, faced with babbitt, resting on a bed of steel springs. In another the stationary ring is divided into quadrants, each supported on a single pivot slightly off center in the direction of rotation. This latter arrangement causes a slight opening at the heel of the

shoe as the upper ring begins to turn, permitting the oil to wedge in between the surfaces as previously described. In the spring-supported type the wedging oil film is obtained by special oil grooves in the plate surfaces. In both types the revolving ring is of polished steel, and the stationary ring or shoes with a rubbing surface of babbitt.

In the larger thrust bearings the oil is continuously circulated by means of a pump which also takes care of the flow to the guide bearings. In the smaller ones the oil is pumped to the guide bearings, but circulation through the thrust bearing is unnecessary. In the large bearings the oil is cooled and filtered before being returned to the thrust bearing. Great care is necessary to keep the bearing submerged in oil and where necessary, to keep it in constant circulation. Flow and temperature indicators and alarms are provided and must be watched by the operator. Owing to the great weight suspended on these bearings, often from 400 to 500 lb. per sq.in., any disarrangement or failure of the oil supply is almost sure to cause serious trouble, as the bearing surface will be destroyed if the oil film is broken, and as a general thing it takes a considerable time to stop one of these units after it is taken off the line, unless powerful brakes are provided, and then it may revolve long enough to ruin the bearing surfaces. As long as the oil film is kept intact and the parts properly submerged in clean, cool oil, the modern thrust bearing is reliable and has contributed largely toward the standardization of the vertical unit for low-head installations during the last few years.

Generator Armature Windings

In the generator the armature windings are almost universally three-phase. There are three distinct paths or circuits through the armature, producing three successive alternating potential waves 120 electrical degrees apart. The three windings may be connected either in Y or delta. The neutral point in the Y connection is sometimes grounded, though on but one generator at one time, on account of internal armature currents that would circulate through the neutral if more than one unit were grounded, heating the wind ings without benefiting the service in any way.

Proper generator voltage is determined by the special requirements of the individual plant. If there is local distribution direct from the plant bus, the generator voltage selected is generally the most efficient voltage for that service. For a long time 2,300-volts has been the standard, but there is a growing tendency toward higher potentials, 4,000, 6,600, 11,000 and 13,200 being in use on many systems. As far as the every-day operation of the plant is concerned, the generator voltage makes but little difference, the advantage, if any, being in favor of the higher or intermediate voltages on account of the smaller current for a given output.

The power factor of the generator has an important bearing on its operation. The induction motor, which constitutes a large part of the power load, has an inherently low power factor, owing to the lagging current required for its excitation. This lagging current loads up the line and transformers and, if not offset by leading current of equal value, tends to lower the voltage by loading the transmission line with extra amperes and by its demagnetizing effect on the generator fields.

Laying aside the more technical aspects of this matter, when the kilovolt-amperes, the product of the volts and amperes, multiplied by 0.00173 in a three-phase circuit, and the indicated kilowatts are equal, there is no wattless current present, the waves of potential and current are in synchronism; that is, they rise and fall together as the waves alternate in direction, and we have 100 per cent, or unity, power factor. This may be approached closely on circuits loaded with incandescent lamps, but a high power factor is rarely maintained in present-day practice on all parts of any system as a whole. There is a growing tendency to install synchronous motors in connection with the induction motors in large industrial establishments, so that the lagging current required by the latter may be taken care of and neutralized at its source. This is not generally practical in small and medium-sized installations.

Correcting the Power Factor

Sometimes a large synchronous motor is floated on the line at a substation where the power factor is particularly bad, having no mechanical load except its own losses, but fully loaded with leading current to offset the lagging current of the local load. A machine thus used is called a synchronous condenser. Individual generators may be maintained at a high power factor, but other units must in that case be given a greater lead to offset the lagging current not taken care of by the favored machine.

When the kilovolt-amperes show a greater value than the kilowatts, the current is either leading or lagging. The kilovolt-amperes or apparent power is the vector sum of the volt-amperes due to the load and the volt-amperes due to the reactive or wattless current, either leading or lagging, due to the causes already mentioned. If there is a power-factor indicator or a reactive-factor meter in the circuit, the relative value of real and apparent power may be obtained. These instruments read unity power factor at the center of the scale so that the reactive current indicated in one direction is leading and in the other lagging. If no instrument of this kind is provided, the power factor may be determined by dividing the indicated kilowatts by the total kilovolt-amperes or apparent power.

Types and Operation of Exciters

The exciter is the source of energy for the magnetic excitation of the generator field. As has been stated, the alternating-current generator is not self-exciting. None of the numerous attempts to make it so, or partially so, have been successful. A source of direct current, electrically independent of the circuits of the generator, must be provided.

This is accomplished by the installation of a small direct-current generator direct-connected or, as in some of the older and smaller plants, belted to each generator shaft, motor-driven from the station bus, or separately driven by small turbines. Sometimes the motor or turbine-driven exciter is of sufficient capacity to excite all or several of the units in the plant.

The exciter is similar to any other direct-current generator. It may be shunt or compound wound, with or without commutating poles, paralleled or not paralleled with other exciters, equipped for hand or automatic voltage regulation. There are many elaborate and complicated ideas of exciter connections, and on the other hand, in many plants of considerable capacity the exciter layout is excedingly simple.

The shunt-wound machine answers all purposes where each generator field is energized solely from its own exciter. A little greater stability is obtained with the compound-wound exciter.

With automatic regulation probably the best exciter is the compound, commutating pole machine. If the plant was originally designed for automatic regulation, the exciters are specially adapted to that condition. If automatic regulation has been installed in an old plant, caution may be necessary in handling the exciters. No general rule can be given that will fit all cases. No two installations, even on the same system, are exactly alike.

Belt-Driven Exciters

In the matter of exciter drive the cheapest design is a belted connection to the generator shaft. The hydro-electric generator is almost invariably slow-speed, so by belt connection a high-speed exciter and therefore a cheaper one, may be used than would be possible if a special slow-speed exciter were built for direct connection to the generator. This is the only argument in favor of the installation of a belted exciter in a modern plant. There are two arguments against it. The exciter, like the generator, must be designed for double speed so that it will not break bands or throw wedges in case the turbine runs away. Any irregularity in the belt, such as a laced joint, will cause a "kick" in the generator voltage that will show in the lighting service and may possibly start a dangerous surging of the load if allowed to continue. The same is true of any belt slippage.

Direct or motor drive has a characteristic that may or may not be a disadvantage. The exciter speed, and consequently its voltage, will vary with the speed of the turbines, and when these are suddenly slowed down by a short-circuit, the exciter will die down with the speed. One possible advantage of this is that an arc on the line will not have the destructive value that it would have if the exciter voltage were kept up to normal, and if there is an automatic switch in the circuit, the short will decrease somewhat before the switch has time to open. Speed variations will show on the generator voltage, unless the exciter is equipped with an automatic regulator. This apparatus permits some irregularity, but cannot hold the voltage during the severe swings that occur in storms and trouble.

Turbine-Driven Exciters

Turbine-driven exciters may either be hand-regulated or may have a governor. It is necessary in either case to exercise caution in regulating the exciter load, especially in paralleling exciters. In many cases the turbine-driven exciter is the first equipment in the plant to feel the effects of anchor ice. The only hope for continued operation in this case is to have the exciter equipped with an emergency motor or belt drive or to have a motor-generator ready to parallel with it at the first sign of distress.

A part of the daily routine should be to keep the exciter clean by blowing regularly with compressed air or a hand bellows and careful wiping with clean cheesecloth. The commutator should be given special attention. If it gets gummy, it should be wiped with cheesecloth slightly moistened with gasoline. If the mica is high or the surface rough, it should be sanded. If it is ridged or rough, it should be smoothed down with a commutator stone. Proper staggering of the brushes, so that the entire length of the bars is in contact with them, should remove the tendency to form ridges. If the commutator is out of round, it should be trued up in a lathe or by means of special turning or grinding tools. The use of sandpaper at too frequent intervals is generally unnecessary. A rich brown glaze is the ideal commutator surface, and as long as this is maintained there is no need of sanding unless high mica or other conditions demand it.

Sparking is entirely out of place in an exciter. If it occurs it is generally due to dirt. If a thorough cleaning and sanding does not remedy, there may be serious trouble impending, and the cause should be sought for and remedied.

Lubricants should be used sparingly on a commutator. A slight application of paraffin wax or a little clean engine or transit oil applied with a piece of clean cheesecloth should be all that is necessary on a flush mica commutator. If the commutator is slotted (undercut) no lubricant should be used, as a sticky mixture of oil and carbon dust will lodge in the slots, and as this is a conductor, it is likely to cause trouble. As the proportion of current carried by a carbon brush depends largely on the contact pressure, the spring tension on all brush-holders should be uniform. If one brush has more pressure than others on the same brush arm, that brush will take more than its share of current and will be likely to heat and spark. For the same reason different makes or grades of brushes should not be used. All of them should be alike.

Regulation of Generator Voltage

The generator voltage is regulated by varying the strength of either the shunt field of the exciter or the generator field by means of a rheostat connected in series with the respective field winding. The rheostat consists of a resistance of iron grids or special resistance wire made variable by taps brought out at regular intervals and connected to corresponding contact points on a dial switch. Where a single exciter is used for more than one generator, or where the individual exciters are operated in parallel, some adjustment of the generator field rheostats is necessary to balance the current between machines properly, but where each generator has its own exciter, ordinary adjustments should be made on the exciter field and the generator rheostat kept cut out, as its use under usual conditions causes an unnecessary waste of energy. In many small plants the generator rheostat is omitted altogether, but in those installations where it is necessary to "buck the line," greater stability of the exciter will be assured if the generator field is weakened by use of the generator rheostat and the exciter voltage maintained at or near its normal value.

In many installations the voltage is controlled by automatic regulators. This is accomplished by the rapid opening and closing of a shunt circuit across the exciter rheostat. Details covering regulator adjustment and operation and full instructions regarding their installation and care are contained in the complete instruction books issued by the makers.

Once properly adjusted for the particular type of exciter and exciter connections and for the load characteristics of a given plant, these regulators are reliable in normal operation and are of great value where a single plant carries or controls a distribution load. In serious line trouble, however, the regulator should be cut out of service, as the line may surge repeatedly beyond its capacity, drawing an arc on the contacts which would soon destroy them. On a system fed by a large number of small or medium-sized plants, the efficacy of the regulator is questionable, owing to the power-factor problems involved.

The Meaning of Cloud and Pour Points in Lubricating Oil

By W. F. Osborne*

WHEN petroleum oils are cooled, they become thicker and more sluggish until a temperature is reached at which they cease to flow. Petroleum oils are mixtures of various hydrocarbons in solution, and each individual compound has a definite melting or freezing point. When the oil is cooled, some of these compounds frequently begin to congeal or solidify before others, and a separation or deposition of solid particles takes place.

A familiar example is the separation of paraffin wax from paraffin-base lubricating oils, giving an opaque appearance to the oil. Oils of naphthene base which contain no paraffin have no cloud point and remain clear until they congeal.

Keeping the oil agitated while it is freezing tends to prevent the formation of crystalline structures, and the oil will remain liquid at lower temperatures than it will if kept perfectly still while cooling. Heating the oil before cooling tends to increase the crystallizing action and results in the oil congealing at a higher temperature than if it had not been heated.

On account of these various influences on the congealing point, the method of determining the cloud and pour tests must be in accordance with carefully worked-out standards in order that the results may have any comparative value. The American Society for Testing Materials defines the *cloud test* as "that temperature at which paraffin wax or other solid substances begin to crystallize out or separate from solution when the oil is chilled under certain definite specified conditions."

Specific Conditions

A usual method for the cloud tests is to place the oil in a tube which is immersed in a bath of cold water or freezing mixture of a temperature 10 to 15 deg. below the expected cloud point. The oil is stirred gently and the temperature of the oil at which cloudiness first appears is noted and taken as the cloud point.

The *pour point* is defined as "the lowest temperature at which the oil will pour or flow when it is chilled without disturbance under certain specified conditions." The details for making standard tests have been worked out by the A. S. T. M. and can be found in the proceedings of that society. They should be followed carefully by all engineers or chemists who purchase oils on the basis of specifications.

The illustration Fig. 1 shows the usual method of making the pour test. Two and one-half cubic inches of oil is placed in a test jar. A thermometer is inserted through the cork and dips ½ in. into the oil. The tube is placed in the tank and quickly cooled by means of cracked ice. When the oil starts to congeal, the tube is removed and inclined for no longer than 10 seconds. The cooling is continued until the tube can be inverted 135 deg. for 10 seconds without the oil flowing. Five degrees are added to the temperature noted, and the result is taken as the pour point of the oil. Fig. 2 shows the several parts of the pour-point testing set.

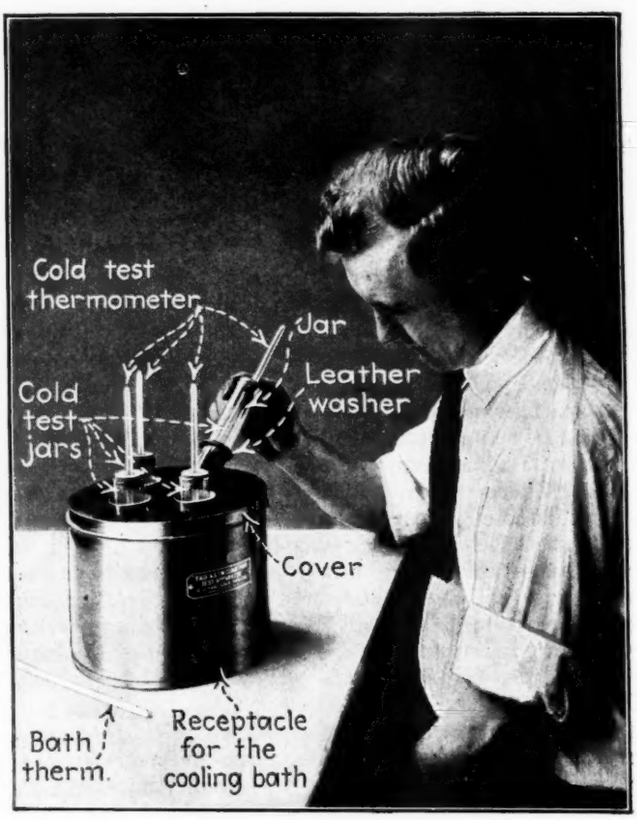


FIG. 1. METHOD OF MAKING POUR TEST

To the practical engineer the pour test is of value because it gives him an idea of the suitability of the oil for the lubrication of bearings exposed to low temperatures. Since the pour test shows the lowest temperature at which the oil will flow, we would expect that it would not be suitable for bearing lubrication at temperatures below this. It must be remembered, however, that the standard test calls for the oil to be chilled without disturbance during the test. Oil in the reservoir of a ring-oiled bearing or in the clearance between a shaft and its bearing is always subject to agitation which prevents the oil from congealing at its tested pour point, and may lower the actual pour point in the case of certain oils, from 15 to 25 deg. F.

On the other hand, the oil in the ring-oiled bearing of an electric motor which has been warmed by the friction of the bearing and by the heat conducted from the armature, if cooled to any great extent after the motor is shut down may congeal at a temperature higher than the tested pour point, on account of the heat effect previously explained.

Oils that contain no paraffin are not so sensitive to these influences of heat and freedom from agitation while freezing. The paraffin lubricating oils have pour-test points of 25 to 35 deg. F., and these may be lowered by a process of refrigeration and cold pressing if the demand warrants the additional expense. The naphthene or asphaltic-base oils have a natural pour test of 0 deg. F. or lower.

Q. I have several electric motors with ring-oiled bearings which operate in an exposed shed in cold weather. I have been told that if I do not purchase a

*Supervisor Manufacturers' Service, Texas Co.

"zero cold-test oil," I cannot get lubrication. What would your recommend?

A. The pour test of an oil, according to A. S. T. M. methods, tells you the temperature at which the oil will cease to flow to a bearing provided it has not been disturbed during the cooling process. If you have any trouble at all, it will come when you start the motor, because the oil in the bearing reservoir will have congealed if the weather is below the pour point of the oil.

This does not mean that you will get no lubrication, because there will undoubtedly be some congealed oil

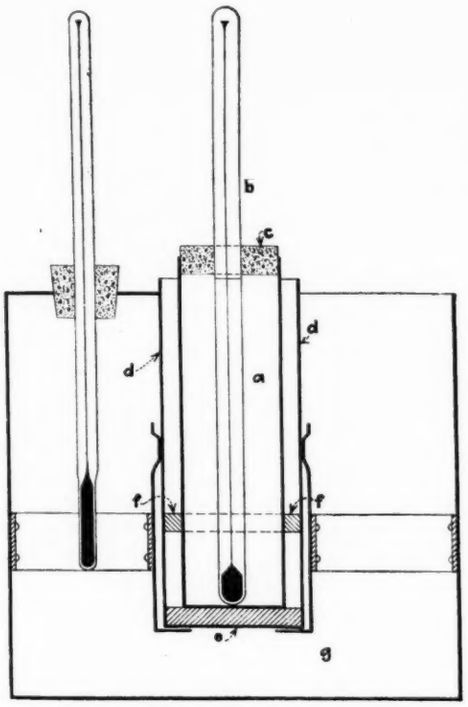


FIG. 2. APPARATUS FOR POUR TEST

a—Test jar 1¼ in. diameter by 4½-5 in. high. *b*—Test thermometer. *c*—Cork to seal jar and hold thermometer. *d*—Jacket to prevent irregular cooling. *e*—Cork or felt base. *f*—Cork or felt ring to hold test jar. *g*—Cooling bath.

in the clearance between the shaft and bearings, which will act as a grease to lubricate the shaft until the heat of friction has melted the oil in the reservoir. This means that the frictional heat may, under certain conditions, have to become very great before the oil in the reservoir will become sufficiently melted to release the oil rings. This condition is particularly aggravated in severe cold weather.

An oil of very low pour test and containing no paraffin wax will congeal only at extremely low temperatures, and the frictional heat required in the bearing for melting the oil will not be nearly so excessive. The question of what pour test should be specified depends entirely upon your lowest operating temperatures.

It may sometimes be thought desirable to clean an old gage glass when it has every appearance of being whole and sound. In such an event, waste or a cleaning cloth should be used and should be pushed through the bore by means of a wooden stick small enough to pass without force. As a rule, however, the price of gage glasses is too low to bother with the cleaning of old ones, and if one shows any deterioration at its ends, it should be discarded in any case.—*The Locomotive.*

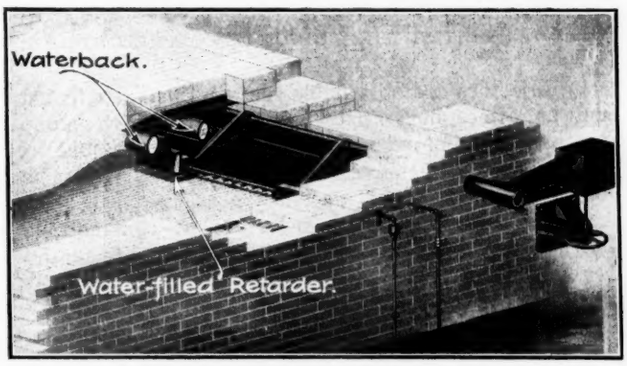
Green Fuel Retarder Adjustable for Firing Rates

The Green Engineering Company has perfected a so-called fuel retarder, an adjustable device to be used with chain-grate stokers for maintaining a compressed fuel bed, for keeping excess air from getting in over the rear end of the grate and for controlling the ashpit losses.

It was the practice, before waterbacks were invented, to burn short fires so that the fuel would be entirely consumed before it reached the ashpit. These short fires had their sure losses due to excess air infiltration, and these losses were not entirely eliminated by the use of louvre dampers.

The pressure waterback, designed a few years ago, went a long way toward solving these problems. It held unburned fuel in the furnace and, by building up a compressed fuel bed, prevented excess air from passing through or entering the furnace around the rear of the stoker. The waterback also made it possible to keep ashpit losses at from 1 to 5 per cent of the fuel fired. Limited flexibility of the device, however, caused it to fall short of completely solving the problems. It could be set to operate successfully at the average rating at which the boiler was expected to be fired, and the stoker height could be varied when the ash content of the coals changed, but there was no method by which the waterback could be adjusted to meet hourly variations in the firing rates.

The fuel retarder, operating in conjunction with a waterback, adds the flexibility desired. It consists of a water-cooled cast-iron box, which spans the grate just back of the waterback. This box is held in such a way that the turning of a wheel outside the setting will vary



SECTION OF THE RETARDER, SHOWING HOW IT IS RAISED AND LOWERED

It can be adjusted to the right height for the thickness of fire being carried, and so makes a compressed fuel bed and keeps out excess air.

the distance between the lower edge of the fuel retarder and the surface of the grate from a minimum opening of 1½ in. to a maximum of 6 inches.

It is claimed that the device makes possible constant operation with compressed fuel beds, regardless of the rating, thus preventing excess air from coming in through the grate, and that it eliminates the necessity for louvre or other dampers under the grate. Clinker and ash accumulations, if formed, can be discharged by raising the retarder. One of the most noteworthy results is said to be a decided improvement in CO_2 readings, due to better combustion.

Practical Information About Injectors*

How the Different Types Work—Advantages and Disadvantages—Applications —Testing—Selection—How to Overcome Operating Troubles

BY TERRELL CROFT

AN INJECTOR (Fig. 1) is a boiler-feeding device consisting of a group of nozzles so arranged that a jet of steam expanding therein strikes a mass of water and condenses. Thereby it imparts its velocity and heat energy to the feed-water, which gains, in this way, sufficient momentum to force itself into the boiler against a pressure higher than the original steam.

Ordinary injectors can discharge against a pressure greater than 130 per cent of the steam-supply pressure.

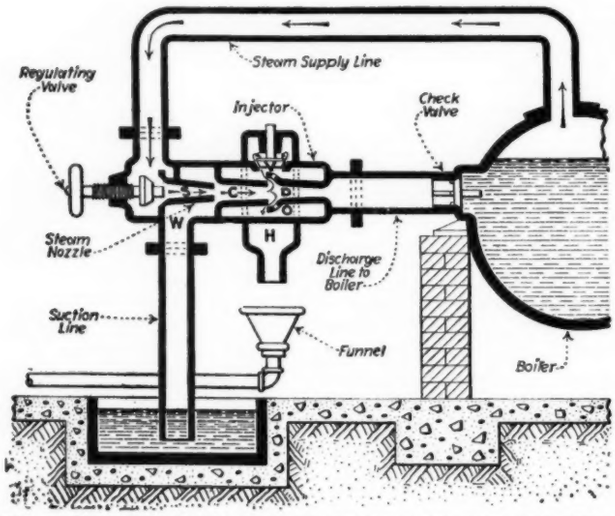


FIG. 1. ILLUSTRATING THE PRINCIPLE OF THE INJECTOR

Special injectors are obtainable that will utilize exhaust steam at atmospheric pressure and therewith pump water into a boiler containing steam at a pressure of 80 lb. gage. A brief explanation of the principles involved will clarify this seeming mystery.

A pound of steam is a reservoir of considerable energy. Expanding, in a well-designed nozzle, from 150 lb. (gage) down to a 24-in. vacuum, about 20 per cent of its heat content is changed into mechanical energy of motion or kinetic energy, amounting to 188,000 ft.-lb. If all this kinetic energy could be utilized, it would force about 500 lb. of water back into the boiler. Over 97 per cent of it, however, is changed back again into heat when the steam jet, traveling at the rate of 40 miles per minute, projects itself against the slowly moving mass of water.

Now, the remaining 3 per cent of kinetic energy (after the 97 per cent has been reconverted into heat) is sufficient, theoretically, to force 15 lb. of water back into the boiler. But pipe friction and other losses cut this down to about 13 lb. of water pumped per pound of steam consumed at 150 lb. pressure. The remaining 97 per cent of the energy which was changed back into heat and the 80 per cent of the original heat content of the steam are not lost, but are absorbed by the feed water and returned to the boiler.

*All rights reserved. This material constitutes a portion of the author's forthcoming book, "Steam Power-Plant Auxiliaries."

The essential parts of an injector are shown in Figs. 1 and 2. These are purposely drawn out of proportion so that the characteristic shapes of the nozzles can be discerned more clearly.

The steam nozzle *S* (Fig. 2) at the left, is so designed that the steam passing through it loses pressure and gains a tremendous velocity. When a pound of steam at ordinary boiler pressure expands down to a partial vacuum, it occupies many times more space than it did at the higher pressure. Now there is not a great difference in diameter between the inlet and discharge openings of the nozzle *S*. Hence it follows that the enormously increased volume of steam must pass through the discharge opening at a correspondingly higher velocity. The combining tube *C* is a cone-shaped nozzle in which the swiftly moving steam jet strikes the water and is condensed. The delivery tube *D* is a diverging nozzle. It receives the combined jet of water and condensed steam and gradually converts most of the velocity of the jet into pressure. This is needed to overcome the head against which the injector is discharging. Overflows *H* are slots or spill-holes, usually located in the combining tube, to permit excess water or steam to escape when starting up. The waste valve *V* is usually a lift or swing check which closes automatically in case a partial vacuum is formed in the overflow chamber *O*. The water in the suction chamber *W* is drawn into the combining tube by the partial vacuum, which is due to the continuous condensation of the steam therein.

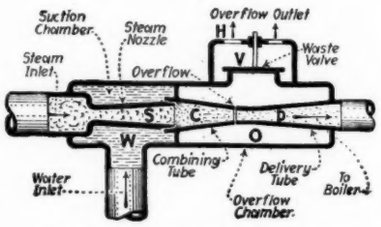


FIG. 2. SECTIONAL VIEW OF ELEMENTARY INJECTOR

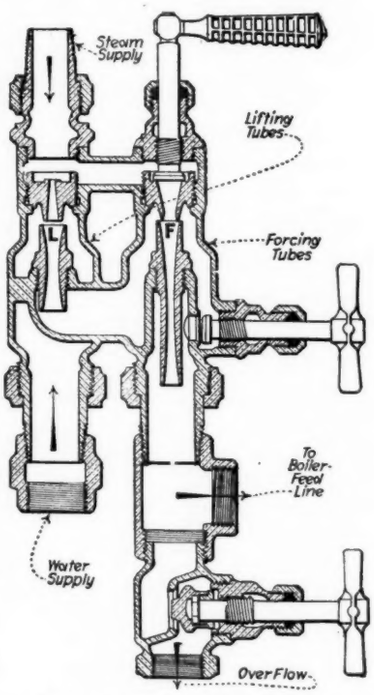


FIG. 3. THE HANCOCK INSPIRATOR (A DOUBLE-TUBE INJECTOR)

Injectors are classified as lifting and non-lifting, depending on whether or not a partial vacuum is created in the suction pipe when starting up. A non-lifting

injector must always be placed below its source of feed water on this account. Injectors that have one set of nozzles *L* (Fig. 3) for lifting the water and another set *F* for forcing it into the boiler are called "double-tube" injectors. Those which accomplish the same result with only one set of nozzles (Fig. 4) are called "single-tube" injectors.

If the operation of an injector automatically re-establishes itself after an interruption in steam or water supply, it is said to be "re-starting," or more usually "automatic." But when the injector must be manually re-started before it will continue to operate, it is said to be "positive." Automatic adjustment for variations in steam pressure or in height of lift and temperature of feed water is a feature of "self-adjusting" injectors. All double-tube injectors, and a special type of single-tube injector that has a moving combining tube, belong to this class. The Sellers self-acting injector is both self-adjusting and re-starting.

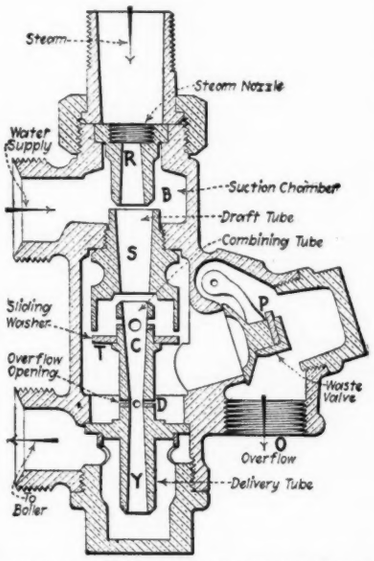


FIG. 4. PENBERTHY SINGLE-TUBE AUTOMATIC INJECTOR

How The Different Types Work

How an automatic injector works is indicated by Fig. 4, which shows a section through a Penberthy automatic injector. This is a "single-tube, re-starting, lifting-type" injector.

In this injector steam enters at the top and, expanding in the steam nozzle *R*, rushes through the draft-tube *S*, carrying with it enough entrained air to create a partial vacuum in the suction chamber *B*. Unable to discharge against the boiler pressure, this steam escapes through the large opening above the sliding washer *T* and through the overflow opening *D*, via *P* and *O*, to the atmosphere.

The partial vacuum in *B* has already lifted water into it, and this water has condensed part of the steam. As more and more of the steam condenses, the jet becomes more compact and finally becomes sufficiently small to pass through the least diameter of the combining tube *C*. Thence it passes through the delivery tube *Y* and a check valve (Fig. 7), to the boiler.

The swiftly moving jet of water and condensed steam creates a partial vacuum in the tube *C*. This draws the loose washer *T* up against its seat. Thereby is prevented any inrush of air which would scatter the jet. The closing of *T* also prevents any loss of feed water through it. If the steam or water supply becomes interrupted, the jet is destroyed and the vacuum above *T* is lost. This allows *T* to drop down to its original position. Hence, upon the resumption of the steam or water supply, the operation just described is repeated.

A positive injector is indicated in Fig. 5, which shows a sectional view of a "Metropolitan Model O" Injector. This is of the positive, double-tube, lifting type, and is operated entirely by one handle.

When the handle *H* is pulled back slightly, steam is admitted to the lower lifting nozzle *N* through the opening of the auxiliary valve *A* and of the regulating valve *R*. The lifting nozzles *N* and *C* now begin to operate. The excess steam escapes through the intermediate overflow valve *O* and thence to the atmosphere through the final overflow or waste valve *F*. As soon as water is lifted, it will reach the overflow through *C*. The operator then pulls the handle back gradually, admitting steam into the main nozzle *M* through the steam valve *V*. The action of this steam in passing through the remaining nozzles has already been explained. By the time the handle has been pulled back as far as it will go, the injector is feeding into the boiler through the check valve *D*, and the link *L* has moved to the left far enough to close the waste valve *F* by means of the bell crank *B* and the stem *S*. The regulating valve *R* is used to control the supply of water to the injector.

Advantages and Disadvantages

The advantages of an injector are: (1) simplicity, (2) compactness, (3) low first cost, (4) high temperature of feed-water delivered, (5) ease of operation, (6) low cost of upkeep and repairs and (7) high thermal efficiency (about 99 per cent of the energy put into it is utilized). The absence of any moving parts is responsible for most of these advantages. There are practically no packing glands to be renewed and no parts to be lubricated.

Cold feed-water sets up strains that endanger the structural strength of a boiler, hence an injector is of peculiar advantage on locomotives, where the lack of space and the use of the exhaust steam for stack draft prevent the installation of feed-water heaters. These same two conditions render the injector particularly applicable on locomotives because of its compactness and because it is many times more economical than the feed pump, if the exhaust from the latter is not used to heat

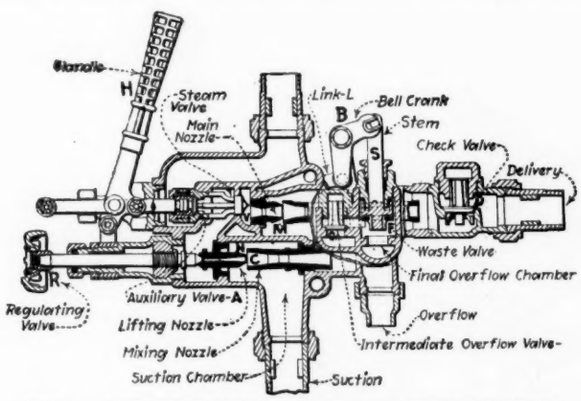


FIG. 5. METROPOLITAN, MODEL-O, DOUBLE-TUBE INJECTOR

the feed-water. Used as an emergency feed, an injector is a valuable piece of equipment involving a minimum of overhead expense.

The disadvantages of the injector are: (1) Inability to handle water that is very hot; (2) irregularity of operation under extreme variation in steam pressure, in temperature of inlet water and in quantity of water handled; (3) efficiency as a pumping unit is extremely low, never over 1 or 2 per cent; that is, when used in ordinary pumping service—not for boiler feeding—an

injector does not compare at all favorably with ordinary pumps in economy.

Few injectors can handle water at 150 deg. F., and most of them become inoperative at much lower inlet-water temperatures. This is the real reason why injectors are not extensively used in large power plants. Such plants always have an ample supply of exhaust steam available from the auxiliaries. If this steam is not used to heat the feed water, it will be wasted.

A feed-water heater placed on the suction side of an injector would heat the water too hot for its successful operation. Placed on the discharge side, a feed-water heater would be inefficient because the injector would deliver water to it at such a high temperature that the heater would not abstract much additional heat from the exhaust steam. To heat feed-water with live steam, when exhaust steam is available, results in poor economy. The irregularity of operation due to the variations mentioned is not, in situations for which the injector is adapted, a serious drawback and necessitates only a reasonable amount of attention from the operator.

How the Different Types Are Applied

The applications of injectors of the different types will now be considered. Whenever it is necessary or desirable to locate the injector above the source of feed, the "lifting" type must be used. The non-lifting type is simpler, cheaper and of special advantage where scale-forming feed water is used, because it will not clog up readily and is easy to clean. Double-tube injectors will handle hotter feed-water through higher lifts than will those of the single-tube type, hence they are used extensively in stationary power plants for emergency boiler feeding.

Re-starting injectors are used in small power plants. The "self-acting" injector was designed for locomotive use, but is applicable where any double-tube type is necessary. Injectors are often used for testing and washing boilers, feeding compound into boiler and similar services. Fig. 6 shows an injector arranged for testing. With the apparatus shown it is possible to determine the steam pressure, lift and temperature of water supply. Then by measuring the amount of water handled per minute and the temperature of the water delivered to the boiler, it is possible to determine the performance of the injector.

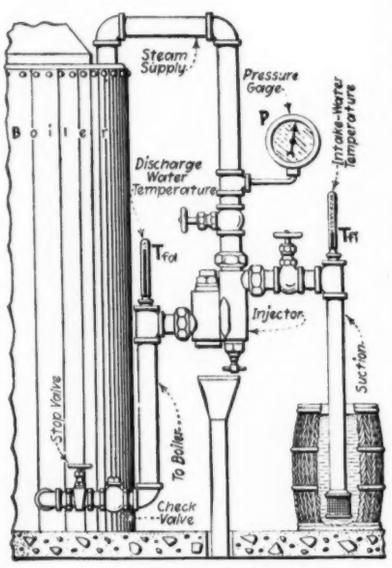


FIG. 6. INJECTOR ARRANGED FOR TESTING

The performance of an injector is influenced by the following important factors: (1) Temperature of inlet water, (2) height of suction lift and (3) steam pressure: The action of an injector depends on the condensation of the steam jet by the incoming water. If this water is too warm, the injector will not start. This limit is called the "overflowing" temperature. After the injector has started, it is possible to operate with an intake water of a higher temperature up to a certain limit called the "breaking" or "limiting" temperature.

The selection of an injector requires careful consideration of the three factors just mentioned. Select an injector with a capacity in gallons per hour that is 30 per cent in excess of the amount of water normally used. The question of what type of injector to use for any given service has already been discussed. It is always best to inform the manufacturer as to the height of lift and average temperature of feed water and the maximum, minimum and average steam pressure, as well as the required capacity of the injector. The injector will not operate at more than its maximum or less than its minimum capacity.

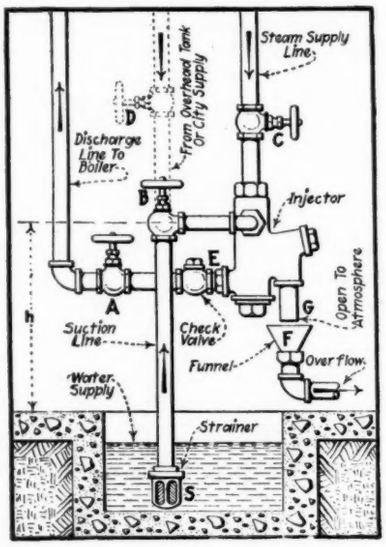


FIG. 7. PIPING OF AN INJECTOR

When installing injectors, the typical piping scheme shown in Fig. 7 may be followed. The steam, suction and discharge pipes are all of the same size, except that in case of a suction lift exceeding ten feet, or of a long suction line, a pipe one or two sizes larger should be used.

The steam line in Fig. 7 should be tapped into the highest part of the boiler and lagged all the way to the injector, if possible. *C* is a globe valve. The discharge line should follow as near a straight line as possible to the boiler-feed inlet, and should be securely fastened throughout its entire length. A check-valve *E* must be installed as shown. *A* is a globe stop valve which can be used to cut off the boiler pressure from the check valve so it may be opened for repair. The overflow is usually piped as shown. It is ordinarily best not to discharge the overflow into the hotwell or feed supply, as it may cause the suction water to become too hot to be lifted. The overflow line must always be open at *G* to the atmosphere. The funnel *F* may be an ordinary one of sheet metal or one of the special "non-splash" types (Fig. 8).

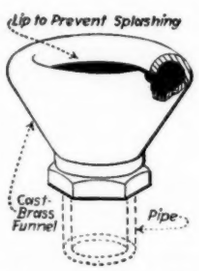


FIG. 8. "NON-SPLASH" FUNNEL FOR INJECTOR OVERFLOW PIPE

The suction line must be absolutely airtight and as free from elbows and bends as possible. The angle valve *B* takes the place of one elbow. The strainer *S* should not have any opening in it as large as the steam nozzle in the injector, and should have a combined area of openings several times as great as the suction pipe itself. Figs. 6, 9 and 10 show commercial strainers.

The distance *h* should always be less than 20 ft. and much less than that if possible. Injectors are on

the market that will lift 25 ft., but high lifts reduce the capacity of an injector as well as its ability to handle hot water. Further they make starting difficult and operation impossible when there is even a small leak in the suction line.

If the injector is fed from an overhead tank (Fig. 11) or from city supply under pressure, it is advisable to insert an additional valve *D* (Fig. 7) which can be permanently set so as to throttle the pressure down to the desired limit. Then the valve *B* is used only for opening and closing the feed line. All injectors should be braced, especially those that are operated by handles. After installing the piping, it should all be blown out with steam before connecting up the injector.

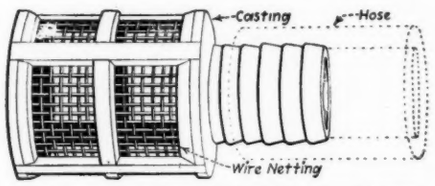


FIG. 9. HOSE-CONNECTION STRAINER FOR INJECTOR SUCTION PIPE

In operating injectors, the procedure is as follows: To start an automatic injector be sure that valve *A* (see Fig. 7) has been left open. Slowly turn the steam valve *C* wide open. Then open suction valve *B*. Next throttle it down until there is no discharge from the overflow. If the suction valve is wide open and steam still escapes from the overflow, it will then be necessary to throttle the steam-supply valve. If the discharge from the overflow is cool water, the suction valve must be throttled. If there are no unusual changes in conditions, the suction valve *B* can be adjusted to give proper supply and then be permitted to remain in that position. An injector like that shown in Fig. 5 is operated entirely by one lever as described in a previous section.

Overcoming Operating Troubles

Injector troubles and their correction are discussed in the following paragraphs. The more important ones are listed. The correction of other difficulties can usually be effected through a consideration of the following information:

If an injector fails to lift water, it may be due to the following causes: (1) Leak in suction line, (2) water too hot, (3) steam pressure too low for the lift, (4) suction strainer clogged, (5) wet steam, (6) nozzles of injector clogged up or covered with scale, (7) waste or overflow valve stuck or leaking, (8) end of suction line not below water or (9) suction hose collapsed by partial vacuum.

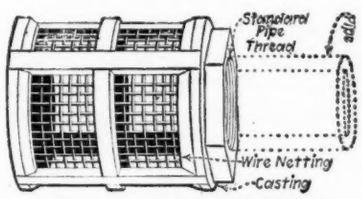


FIG. 10. PIPE-CONNECTION STRAINER FOR INJECTOR SUCTION PIPE

To test for leaks in suction line, screw a cap on the end of the line in place of the strainer. Then wedge the waste valve shut with a piece of wood. When steam is turned on, the leaks will be detected easily. Steam is likely to be wet unless taken from the top of the boiler and led directly to the injector. If nozzles are clogged with scale, they can be removed and cleaned. Coatings of lime can be removed by soaking the nozzle several hours in a solution of ten parts water and one part muriatic acid.

If an injector lifts water but does not deliver to the boiler, the trouble may be due to (1), (3), (5), (6) and (7) of the foregoing and may also be caused by (10) faulty boiler check valve or (11) obstruction somewhere in delivery pipe. In case of the latter two difficulties, close valve *A* and examine the check valve. If it is lifting properly, leave the cap off and take out the disk. Then start the injector. If a full stream of water shoots out of the check valve, then there is an obstruction between it and the boiler (most probably inside at the opening of the feed pipe).

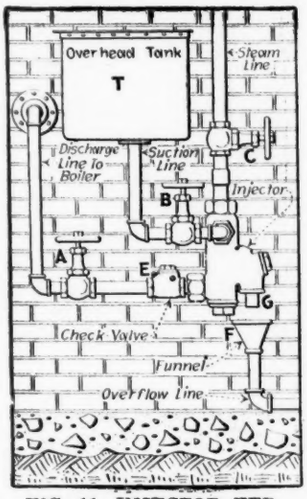


FIG. 11. INJECTOR FED FROM OVERHEAD TANK

If the injector starts but breaks, the trouble may be due to (1), (3), (6), (11) and also to (12), an improper adjustment of the water supply. If water at the overflow is hot, then the supply is inadequate and should be increased by opening the valve *B* wider. If it is cold, then the supply should be throttled by means of valve *B*.

When steam appears at the overflow the fault may be (2) or (4) or (13) too-high steam pressure for the lift. In this case, throttle down the valve *C* until the overflow discharge ceases. Every user of injectors should preserve a set of directions for removal of injector parts and should have available spare nozzles for repairs. Directions are gladly furnished by the manufacturers.

Comments on the Smoke Problem*

Most, but not all, of the conditions necessary for smokeless combustion can be summed up under the one word "uniformity." Smokeless combustion requires the maintenance of a uniform and proper supply of fuel and air under conditions of suitable temperature, mixing and volume of combustion space.

A bed of coal cannot find uniform conditions if the coal is fed in large lumps. Intermittent hand-firing cannot produce a uniform supply of fuel, since immediately after introducing coal into a fire a large quantity of volatile matter is distilled, calling for a large amount of air to burn it, while less air is required after the volatile matter has burned off. For this reason there is, ordinarily, a deficiency of air immediately after firing and, usually, an excess for the remainder of the time. Uniform, continuous mechanical feeding of coal is, therefore, the ideal way to supply fuel.

Uniform mixing of air with the coal products is one of the most difficult things to attain. Irregular thickness of the fire, accumulations of ash and clinkers in the grate, placing large amounts of coal on the fire at one time, opening of firedoors, all contribute to an irregular and variable supply of air when uniformity is desired, so that continuous mechanical operation aids again in approximating an ideal air supply.

*Abstract of portion of Bureau of Mines Investigation Report No. 2323, by O. P. Hood.

Reasons for the Peculiar Shapes of the Back Pressure Line of the Indicator Diagram

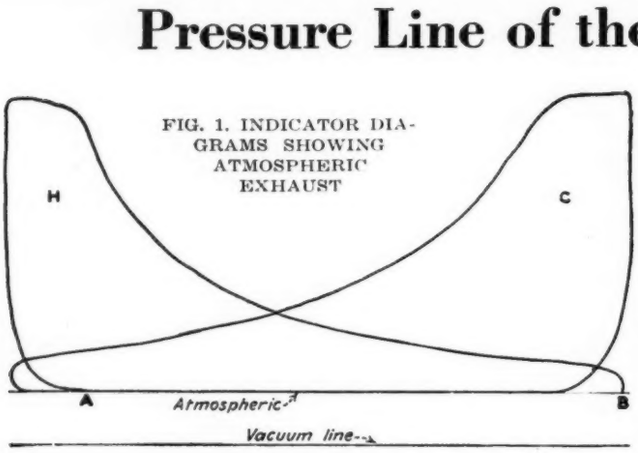


FIG. 1. INDICATOR DIAGRAMS SHOWING ATMOSPHERIC EXHAUST

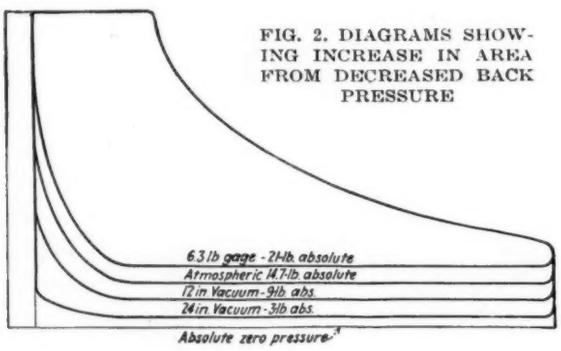


FIG. 2. DIAGRAMS SHOWING INCREASE IN AREA FROM DECREASED BACK PRESSURE

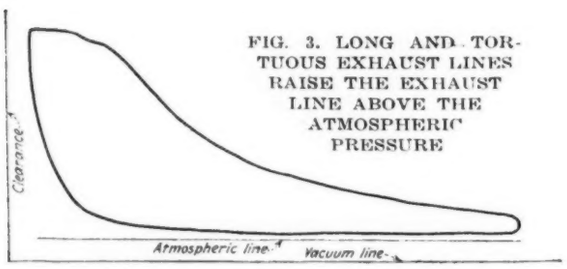


FIG. 3. LONG AND TORTUOUS EXHAUST LINES RAISE THE EXHAUST LINE ABOVE THE ATMOSPHERIC PRESSURE

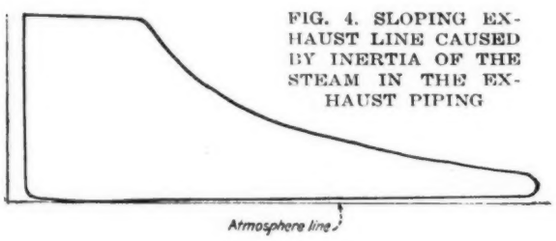


FIG. 4. SLOPING EXHAUST LINE CAUSED BY INERTIA OF THE STEAM IN THE EXHAUST PIPING

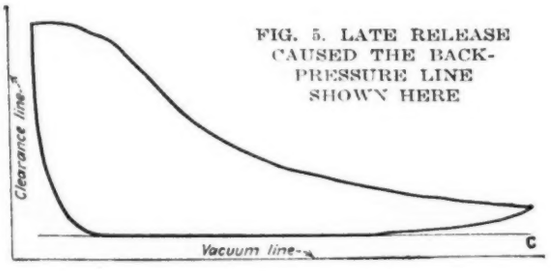


FIG. 5. LATE RELEASE CAUSED THE BACK-PRESSURE LINE SHOWN HERE

AFTER the steam in expanding has forced the piston to the end of its stroke, it is of no further use in the cylinder and should be gotten rid of at once. This, as indicated in the last article on the indicator, is accomplished by the opening of the exhaust valve, allowing the steam, which is usually at a pressure somewhat above that existing in the exhaust line, to pass out of the cylinder. With properly designed exhaust ports and valves the cylinder pressure should at once drop to that of the receptacle into which the steam passes, be it a condenser or the atmosphere or a heating-system line. After the piston reverses and moves on its return stroke, the steam which still fills the cylinder at a pressure equal to or slightly above the pressure existing in the exhaust line, is displaced by the piston movement and pushed out through the exhaust valve. Since the piston on this return stroke is working against the pressure indicated by the counter-pressure line on the indicator diagram, the desirability of having this pressure as low as possible is evident.

Effect of Decreased Back Pressure

In Fig. 1 we have diagrams from an engine exhausting directly into the atmosphere. On the head-end side of the piston we have the boiler pressure which is at, say, 100 lb. gage, or 114.7 absolute. The pressure shown on a steam gage is not the total pressure existing within the boiler or cylinder, but the difference between the inside pressure and the pressure of the atmosphere pushing inward on the boiler. In other words, it is the *net* pressure tending to disrupt the boiler. On the crank-end side of the piston (assuming the crank end exhaust valve to be open) we have the pressure of the atmosphere, here taken at 14.7 lb. absolute. The pressure on the left-hand side of the piston not only does work in carrying the engine load, but must also overcome this atmospheric pressure in the other end of the cylinder. If the boiler were located at a high altitude, the back pressure would no longer be 14.7 lb., but lower, say 13 lb. If the boiler pressure were still 114.7 lb. absolute and the point of cutoff the same so that the number of expansions were constant (which would give the same average pressure exerted on the piston by the steam in the head end of the cylinder) the engine would be able to pull a greater load, since a smaller amount of energy is spent in pushing the lower-pressure steam out of the crank end.

If the exhaust were connected to a tank that was maintained at 13 lb. by means of an air pump that could duplicate the high-altitude conditions, the back pressure would be lower than atmospheric and more power would be secured per pound of steam fed to the engine. This is the object of the condenser, which, by condensing the steam and removing the air in the exhaust connection and condenser, creates a low-pressure atmosphere. The steam, which would speedily fill the condenser and raise the pressure, is condensed by cooling water. In Fig. 2 are shown diagrams from an engine operating under a back pressure, atmospheric pressure and two condenser pressures. It will be observed that the lower the back-pressure line the greater is the *net* pressure on the piston at all points in the working stroke.

If the exhaust opening and the pipe line are ample,

the back or counter pressure will practically coincide with the pressure of the receiving space, which in Fig. 1 is the atmosphere. The use of exhaust lines of insufficient diameter and with numerous fittings causes additional resistance which must be overcome by the steam in passing out through the lines. The pressure drop required to overcome the resistance may be several

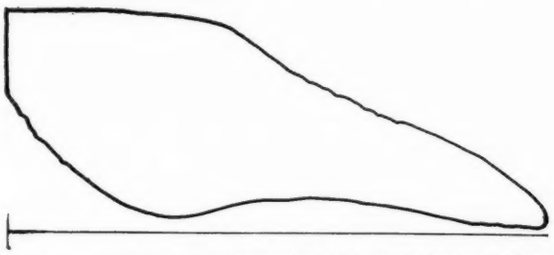


FIG. 6. HUMP CAUSED BY SMALL EXHAUST PORT OPENING

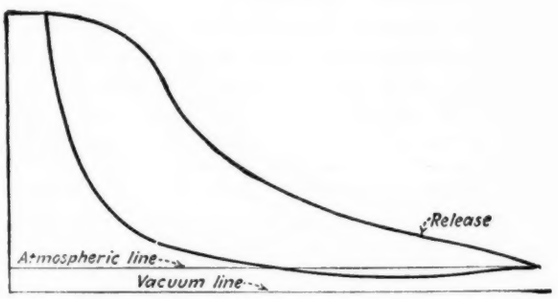


FIG. 7. PARTIAL VACUUM CAUSED BY NOZZLE EFFECT OF EXHAUST PORTS

pounds, raising the back-pressure line above the atmospheric, as shown in Fig. 3.

A frequent type of back-pressure line is shown in Fig. 4, which was taken from a slow-moving Corliss. The pressure at the beginning of the stroke is somewhat above atmospheric, but steadily approaches this line as the piston continues on its return or counter-pressure stroke. This condition may be taken as evidence that the exhaust line is of considerable length. The inertia of the long column of steam in the exhaust pipe is such that a comparatively large pressure drop is required to set the column into motion. After the slow start the resistance decreases and the counter-pressure line on the indicator diagram drops as shown. This is of more frequent occurrence on slow-speed engines with small exhaust pipes than it is on high-speed engines. This for the reason that with higher speeds the column of steam in the exhaust pipe does not come to rest before a fresh charge of exhaust steam is expelled out of the engine. A late opening of the exhaust valve will cause the back-pressure line to hold up at the beginning, as in Fig. 5. The higher the terminal pressure the more aggravating this dragging effect is likely to be. In a rolling-mill engine, for instance, where during the moment of greatest load full pressure is carried throughout the stroke, the piston may have covered a large portion of its return stroke before the cylinderful of high pressure steam reaches normal back pressure.

The line may have a pronounced hump as in Fig. 6. Owing to the angularity effect of the connecting rod, with the piston on the head-end forward stroke (the crank-end exhaust stroke) when the crank is at mid-position, the piston is past the center of the stroke. On the crank-end forward stroke, when the crank is at mid-position, the piston has not reached the middle of its travel. The piston on the head-end stroke must then move a shorter distance or at a slower speed while the crank completes the second half of its travel than it moves during the crank-end stroke in the same number of degrees or units of time. More steam is displaced out of the head-end exhaust port during the second part of the crank travel than is displaced out of crank-end exhaust port in the same length of time. The displacement of the large amount of steam causes a pressure drop through the head-end exhaust port, giving the hump in Fig. 6.

In duplex engines exhausting into a common line the back-pressure line will frequently show evidence of a rise in pressure at midstroke even at low loads. Such engines are ordinarily set quartered, and the release in the other cylinder allows a large volume of steam under a pressure above that of the exhaust line to blow into the passage through which the cylinder being indicated is exhausting.

This effect has been overcome by Professor Stumpf on a locomotive by making the exhaust from one cylinder, by the use of an eduction nozzle, assist instead of hinder the exhaust from the other cylinder. A diagram from a unaflow cylinder so arranged on a locomotive is shown in Fig. 7. It may be quite possible to utilize on this principle considerable of the residual energy of the exhaust steam in reducing the back pressure; in transferring the energy represented by the area *A* and *B* of Fig. 8 outside the diagram to that represented by the area *C* inside the diagram. By making the release earlier than usual by *fd*, the area *F* is

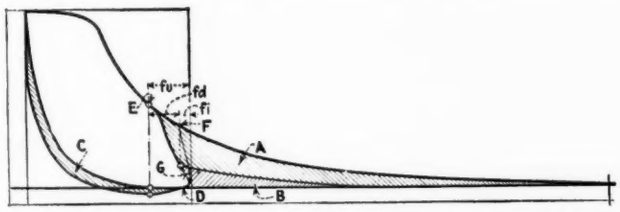


FIG. 8. CONVERSION OF UNAVAILABLE ENERGY INTO AVAILABLE IN A DUPLEX UNAFLOW ENGINE

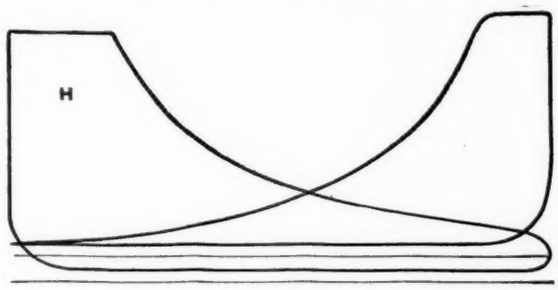


FIG. 9. DIAGRAMS WITH DIFFERENT BACK PRESSURES IN THE TWO CYLINDER ENDS

lost, but the area *C* gained is much greater. Frequently, in textile mills one end of the cylinder is connected to a condenser while the other end discharges into the heating or steam process lines at several pounds pressure. Fig. 9 shows an engine operating under these conditions. The forward pressure on the head end must overcome the back pressure in the crank end, so that with a high crank-end back pressure the head-end cut-off must be later than that of the crank end if the average net forward pressure is to be the same for both ends, and the turning effort equal.

The Gain in Force By Mechanical Appliances

ONE general rule covers the lever, block and fall, screw jack and any other apparatus used to multiply force. This rule may be easily learned and put to practical use.

Can You Figure It?

IT IS often desired to figure the multiplication of force that can be obtained by various mechanical appliances, such as block and fall, lever, screw jack, hydraulic jack, etc. Leaving friction out of consideration, it is a simple matter to figure the mechanical advantage of such devices. Moreover, it is not necessary to learn a separate rule for each. There is one old principle of mechanics that will turn the trick for any of them. With this clearly in mind all other rules may be discarded.

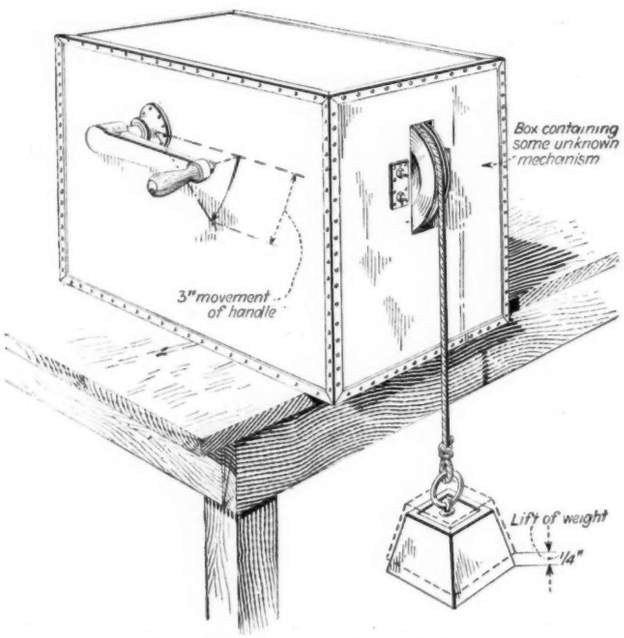


FIG. 1. THE CRANK RAISES THE WEIGHT BY MEANS OF AN UNKNOWN MECHANISM

Without knowing the mechanism in the box, it is found that the weight is lifted ¼ in. whenever the handle is moved 3 in. Since the hand moves twelve times as far as the weight, the latter (neglecting friction) will be twelve times the force exerted by the hand.

The Principle of Work

The law is this: "In a frictionless machine the work put in is equal to the work taken out." "Work" is force exerted times distance moved. After figuring the answer by this principle, a deduction may be made for the estimated friction.

To show how general is the application of this principle, assume that it is applied to a machine whose working we do not understand. Suppose the machine is in a box where we cannot see the mechanism. On the outside it looks like Fig. 1. To try out the appliance, the crank is turned at a steady rate, and it is discovered that the weight is raised at a constant speed. When the end of the crank is moved 3 in., it is found that the weight is raised ¼ in.

According to the law just given, the work done by the hand is equal to the work delivered to the weight. That is to say, the force you apply times the distance the hand moves, must be equal to the weight times the distance it is lifted. We have just seen that the hand moves twelve times as far as the weight. To make the two products equal, the weight must be twelve times the force applied by the hand. What is lost in distance is made up in force. So if you apply 30 lb. at the crank, you can raise $30 \times 12 = 360$ pounds.

Block and Fall Easily Figured

Now let us apply this same idea to other appliances. Consider the block and fall shown in Fig. 2. Here the weight is supported from the upper block by four ropes. If the hand moves 12 in., as shown, it takes up a *total* of 12 in. from the four ropes that support the weight, or 3 in. from each. It is obvious then, that the weight must rise 3 in. Since the hand moves four times as far as the weight, the weight is four times as much as the pull exerted by the hand.

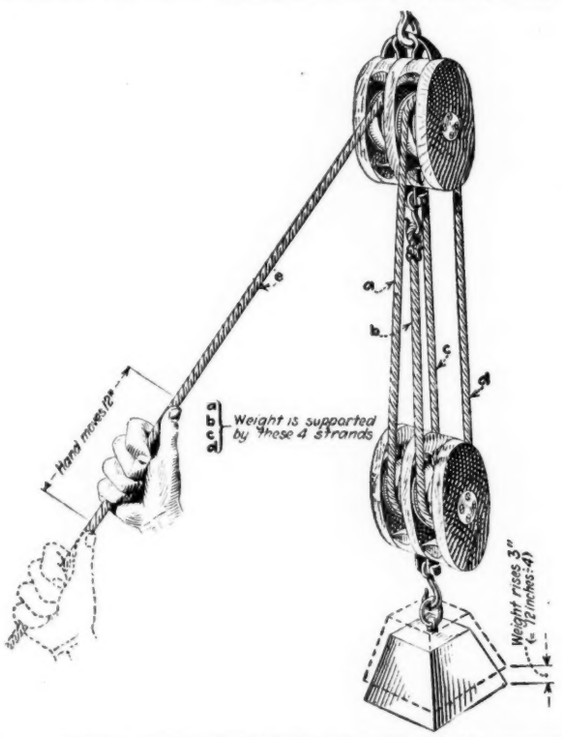


FIG. 2. SINCE FOUR STRANDS SUPPORT THE WEIGHT, THE FORCE OF THE HAND IS ONLY ONE-QUARTER OF THE WEIGHT

Another way to figure this problem is to say that the tension is the same in all parts of the rope. The weight is *supported* by four ropes so the tension in each must be one-quarter of the weight. The tension in the section *e* is the same as in the rest of the rope, and equal to the amount the hand must pull. Hence the pull of the hand equals one-quarter of the weight.

Next take the case of a lever, Fig. 3. Here the weight is 1 ft. from the fulcrum and the hand 5 ft., so the hand will move five times as far as the weight. Since the hand moves five times as far, the force it exerts will be only one-fifth of the weight.

The Screw Jack

A screw jack, such as that shown in Fig. 4, seems more complicated, but the idea is exactly the same. The hand is applied to the bar at a point 20 in. from the center of the screw. Give the bar one turn and see what happens. The hand moves in a circle of 20 in. radius. The total distance moved by the hand is the circumference of a circle of 20-in. radius, or $20 \times 2 \times 3.1416 = 125.664$ in. Call this 125 in., for short. The pitch of the screw is such that the weight rises one-fifth of an inch during this time; so the hand moves $5 \times 125 = 625$ times as far as the weight. Therefore, if there were no friction, each pound of force applied by the hand would lift 625 lb. In this case the friction is considerable, and a large deduction, based on experience, must be

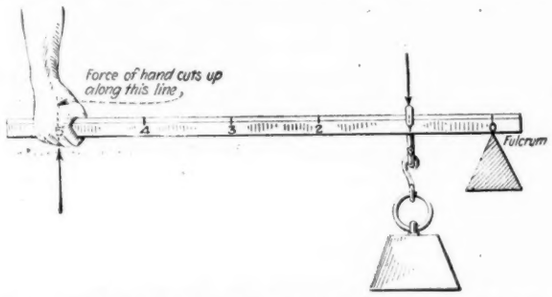


FIG. 3. THE HAND MOVES FIVE TIMES AS FAR AS THE WEIGHT AND EXERTS ONE-FIFTH THE FORCE

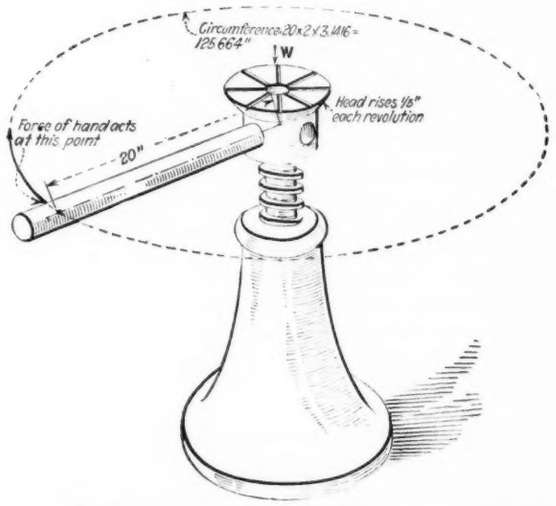


FIG. 4. NEGLECTING FRICTION, THIS JACK MULTIPLIES THE FORCE 625 TIMES

made for it, in order to get the weight that could actually be lifted.

Fig. 5 shows a hydraulic jack. Without seeing or understanding the mechanism, it is found by trial that each time the hand moves down 5 in. the head rises $\frac{1}{64}$ in. So the hand moves 320 times as far as the head, and the weight lifted (neglecting friction) would be 320 times the force applied by the hand.

The same method can be applied to any machine for increasing force. If it is not possible to measure the relative movements on the actual machine, a drawing or paper model may be made and the distances moved obtained from it by trial.

What To Do When the Leverage Varies

In all the appliances so far considered, the movement of the weight, or resulting force, bears a constant ratio to the movement of the applied force. Some types

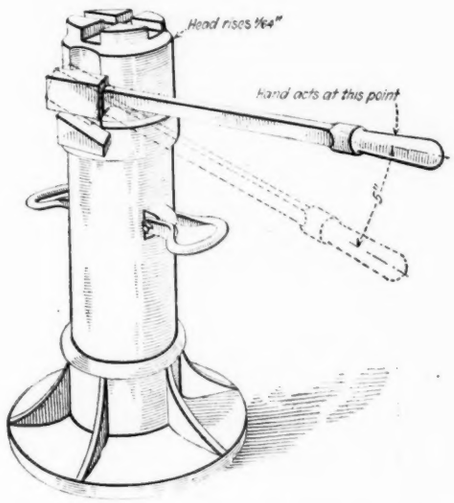


FIG. 5. THIS HYDRAULIC JACK MULTIPLIES THE FORCE 320 TIMES

of apparatus, such as the toggle joint, have a variable ratio. In such cases the law that "the work put in is equal to the work taken out" still holds, but the method described in this article gives the *average* forces over the distance moved. The actual forces at any position can be closely approximated if the movements are made small enough.

Boiler-Room Don'ts

Don't replace a gage glass without first shutting off the valves on top and bottom of the water column, which are provided for the purpose.

Don't tighten up or use a wrench or hammer in any form on leaking manholes while pressure is on the boiler.

Don't enter a boiler while valves are leaking into the boiler until such valves are repaired and put in safe condition.

Don't stand over or use a hammer or wrench on a safety valve that is not working while pressure is on the boiler.

Don't work on a steam line with boiler pressure on it without first relieving the line of that pressure.

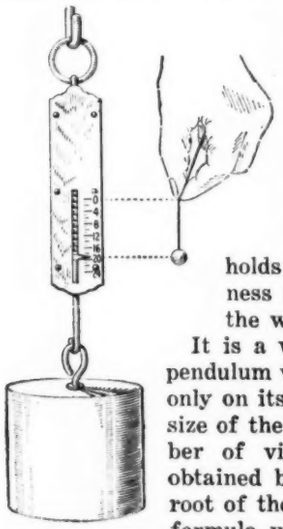
Don't use shovels that have cracked or broken handles or that have been wired up. These should be reported to the foreman for replacement.

—*From Safety Handbook, Texas Power and Light Co.*

A survey of the fusibility of coal ash from various coals of the United States has been completed and the data tabulated for publication in a bulletin of the Bureau of Mines. It is now planned to investigate the relation of laboratory fusibility tests to clinker formation in the burning of coal under actual operating conditions.

An Interesting Experiment in Vibration

In a bulletin recently issued by the Vibration Specialty Co., a simple illustration is given of one of the laws of vibrating bodies. The figure, based on one in this bulletin, shows a spring scale carrying a weight. It also shows a simple pendulum, consisting of a small metal ball on the end of a string. The length of this pendulum is equal to the distance the spring is elongated by the weight.



WEIGHT VIBRATES IN TIME WITH PENDULUM

If the weight is made to bounce up and down while the pendulum is swinging, it is found that both vibrate the same number of times per minute. The surprising thing about this is that it holds true regardless of the stiffness of the spring or the size of the weights.

It is a well-known fact that a simple pendulum vibrates at a rate that depends only on its length, without regard to the size of the weight at the end. The number of vibrations per minute can be obtained by dividing 188 by the square root of the length in inches. This same formula will give the number of vibrations per minute of the weight attached to the spring balance, if the deflection it produces is substituted for the length of the pendulum. Any outside force that acts in step with the natural "period" of the vibrating body will in time build up vibrations, large in comparison with the force.

Brock Feed-Water Purifier

Following some five years' experimental and preparatory work, the Brock Engineering Co., Inc., of St. Louis, Mo., is bringing out a feed-water purifier which separates the scale-forming matter from the feed water before it enters the boiler and tends to improve the circulation. It may be applied to any type of boiler, the intake of the purifier being connected to that point where the highest water temperature is maintained and the outlet to the coldest section. The piping connections in both cases are below the water level in the boiler.

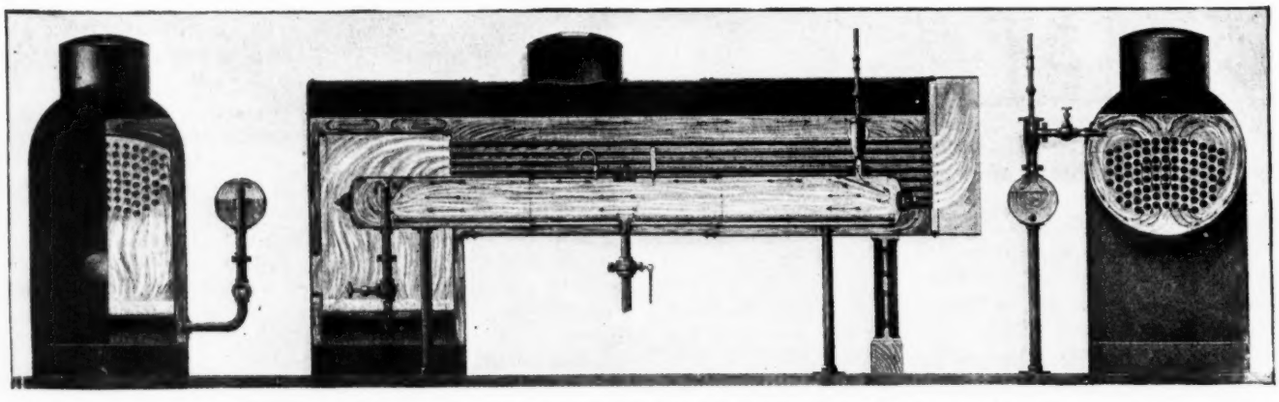
Feed water from the pump or injector enters at the top of the mixing chamber above the purifier, through the nozzle outlet indicated in the accompanying illustration, presenting sectional views of a firebox boiler. A siphoning effect is produced which induces a flow of hot water from the boiler to mix with the feed water and maintain a temperature in the purifier ranging from 250 to 300 deg. F. From the mixing chamber the water is discharged upon a baffle plate within the purifier, causing it to spread and enter the purifier quietly. As the temperature of the water entering the purifier is greater than that in the lower part of it, the path of the circulation is toward the top of the barrel of the purifying unit, thus allowing the impurities a comparatively quiet place to settle until blown off.

At the opposite end of the purifier the circulation strikes another baffle and must go down before rising to discharge into the outlet. Precipitation of the scale-forming matter is completed at this point. Thus only comparatively clean water goes to the boiler. The sediment is precipitated to the bottom of the purifier and at proper intervals is blown off through the perforated pipes located near the bottom of the purifier drum. The proportions of the purifier are such that the water travels slowly, so that the impurities have time to precipitate and settle before reaching the outlet, the interposition of baffles preventing any backlash effect. Another advantageous feature is the fact that no cold water reaches the boiler, the discharge from the purifier being nearly at the same temperature as the water within the boiler.

When the pump, or source of feed-water supply, is not in operation, a natural circulation takes place, so that the temperature within the purifier is maintained. The valve in the pipe line from the boiler can be regulated to suit requirements by varying the amount of water from the boiler admitted to mix with the feed water, thereby controlling the natural circulation at times of non-operation of the pump.

As indicated in the illustration, the device is comparatively simple; no part of it is exposed to the fire or the hot gases, and as the purifier is thoroughly insulated, its functions are performed with practically no loss of heat. A modification not shown in the illustration has a dome on the upper section to take care of the air and gas accumulation through an automatic relief, also two blow-off connections in place of one.

Ordinarily, the magnetizing current of single-phase transformers varies between 4 and 12 per cent of full-load current. In particularly well designed transformers the magnetizing current is as low as 1 per cent of full-load current. On three-phase transformers the phase magnetizing current is from 1 to 12 per cent of full-load phase current.



SHOWS THE PURIFIER APPLIED TO THE LOCOMOTIVE TYPE OF BOILER

EDITORIALS

Receiver Explosion Indications

THAT non-fired pressure vessels, even where intended to carry moderate pressures, can be as hazardous as any steam boiler, is demonstrated by the air-receiver explosion in Kansas City, described elsewhere in this issue. There was a toll of seven lives and twenty-one injured. Had the accident occurred later in the day, the fatalities would have probably been greater as the second-story office, which was demolished, would have been occupied.

At this writing complete information is lacking, but the size of tank (five feet diameter), with a pressure of one hundred and ten pounds, would indicate that it was riveted rather than welded. Making allowance for the probable efficiency of joint would show a factor of safety of from four to five, the plate thickness being three-eighths of an inch. Moreover, there was a pressure gage, safety valve, automatic unloader and an attendant present. It would, of course, be possible that all these had failed to detect or respond to a dangerous rise in pressure, but this is unlikely. On the other hand, ignition of accumulated oil in the receiver might be expected to produce just what happened, especially if it had been the practive to feed too much lubricating oil.

The report of the coroner's inquest will be anxiously awaited, particularly by those concerned with the promulgation of rules for the construction and operation of non-fired pressure vessels.

Water-Rate Factor Has Many Possibilities

AS POWER-PLANT engineering has developed with all its ramifications, various ratios or, as they are generally called, "factors" have been evolved to assist in giving a simple numerical picture of certain sets of conditions in the plant or power system. Many of these factors are very useful and serve a real purpose. A much better understanding of a load curve is obtained when the load factor of the plant is known than can be had by simply ascertaining the value of a few points on the curve. The load factor gives the ratio of the average load to the maximum during a certain period and shows in a one- or two-figure number just how constant the load has been on the plant.

In the article, "Efficiency Tests of a Sixty Thousand Kilowatt Turbine," in the issue of March fourteenth, the authors make use of what they term a "water-rate factor." This factor has been used to make a comparison of the flatness of water-rate curves of different turbines and has been taken as the ratio of the best water rate to the average water rate for a given range of load, such as between one-half and full load. This ratio, irrespective of the shape of the curve, tells just how flat the curve is between whatever ranges of load may be chosen.

A comparatively flat curve may be caused to appear steep by making the ordinate values long and the abscissa short, or a drooping curve can be made comparatively flat by making the ordinates short and the abscissa long. This makes it necessary, before drawing conclusions from any curve, to consider carefully the values at a number of points on the curve. If a factor was marked on the curve giving the ratio of the average value between half-load and full load to full-load value, or for any range of load that might be desirable, the flatness of the curve is then known without further consideration. If the water-rate factor is ninety-eight per cent between half and full load, the conclusion can be drawn that the curve is within two per cent of being flat between these limits. If the water-rate factor is ninety per cent, this would indicate a curve having a considerable droop, irrespective of its shape.

The principle applied in obtaining the water-rate factor can be applied to efficiency curves, or in fact to almost any curve showing the performance of power-plant equipment, to indicate their shapes between certain limits. The value could be obtained in the same way as for the water-rate curve and the factor given a name applicable to the curve to which it applies. It is realized that so many different factors have been adopted or proposed that a factor encyclopedia is almost a necessity. However, this should not be allowed to stand in the way of adopting others that will assist in making engineering data more easily comprehended. In this respect the principles involved in obtaining the water-rate factor of a turbine appear to have wide possibilities in their application to other engineering information.

A Suggested Cure for Perpetual-Motion Hunters

IT IS surprising to see how many men are still wasting their time and energy in the pursuit of perpetual motion. At this very moment hundreds are pegging away at the hopeless problem. This would be laughable if it were not so pathetic. Here is a sad waste of human energy and mechanical ability.

It is by no means true that all those working on this "problem" are mentally unbalanced or lacking in ordinary mechanical sense. Even George Westinghouse, the famous inventor of the air brake, spent several years of his life in chasing this phantom. All these seekers after perpetual motion have one characteristic in common. They do not understand the law of conservation of energy, or if they do, they do not believe it. Yet this law has the same standing in science and engineering as the fact that the world is round. It corresponds with every known fact of nature. Directly and indirectly it has been checked thousands of times, yet no exception to it has ever been discovered. According to this law no machine can, in the long run, give out more energy than is put into it, nor can it give less. In all known machines there is some friction resulting in heat. The remaining output of *mechanical* energy must then be less than the total input of energy. Even if friction could be completely eliminated, a self-operated machine could deliver no mechanical power, although it could

undoubtedly continue to keep up its own useless motion. The law of the conservation of energy shows that perpetual motion is impossible. In addition, a man with a sufficient knowledge of mechanics can prove in other ways that any given design is unworkable. But this requires a separate proof for each machine.

The steps in curing the perpetual-motion inventor—where he is curable—are three: First, analyze the forces in his particular machine and show him by the ordinary laws of mechanics why it will not work; second, if this fails to convince him, let him build a model and find out for himself that it does not work; third, to keep him from starting off on some other tack, explain the law of conservation of energy and show him how it always checks with the facts in every problem of science and engineering.

Evaporators in Small Boiler Plants

MANY large power plants that have been built recently are furnished with evaporators to provide makeup, which in these stations has been reduced, through careful design, to a small percentage of the boiler feed. The elimination of boiler cleaning, the increased efficiency resulting from clean boiler tubes at all times and the favorable heat balance obtained have all combined to justify the addition of the evaporator to the plant equipment. What are the possibilities of evaporators in smaller boiler plants?

Boiler plants to serve turbines of two thousand five hundred to twenty-five thousand kilowatts total capacity usually require a relatively large percentage of makeup water due to leaks, waste and unfavorable heat balance. This makeup may be raw water or treated water, but in almost every case some scale-forming materials are carried into the boiler and have to be removed by tube cleaners and other devices. Boiler plants of the Middle West are troubled with alkali water and soda, while those in the mountain states have to contend with calcium and magnesium bicarbonates and sulphates frequently present in large quantities. Small plants seldom keep accurate records of the cost of water treatment and boiler cleaning, and accurate estimates cannot be made of the decreased boiler efficiency due to scale-coated tubes. The expense due to these conditions is much higher than is generally thought.

An evaporator would eliminate these charges and would improve the general plant efficiency. Hence the desirability of extending its use to the small boiler plant. The problem of the evaporator for such a plant is somewhat different from that of the large plant. An evaporator for such service must meet the following requirements to warrant its wide adoption:

First, it must be relatively cheap—not exceeding a few dollars per kilowatt of plant capacity. A power-plant owner who lacks accurate cost records incident to his present methods of providing for makeup, will not consider any high-priced equipment for this service.

Secondly, the evaporator may be operated by high-pressure steam from the boilers, exhaust steam from auxiliaries or steam bled from the main unit, and its heat cycle must be so regulated that practically all heat used in the evaporator is recovered by the condensate, thereby maintaining favorable heat balance. This will ordinarily not require more than two effects to be used.

Thirdly, the evaporator must be simple to operate and be readily understood, so that it will need no more attention than other auxiliary apparatus.

Fourthly, some apparatus must be combined with the evaporator system to insure the complete removal of oxygen and carbon dioxide from the boiler-feed water. Several such gas-removal equipments are now on the market so that this is not a serious difficulty.

Fifthly, all steam leaks must be stopped and all drips recovered in plants where evaporators are installed, and close attention must be given to heat balance so that the amount of makeup water required will be reduced to a minimum. This in itself will tend to improve over-all efficiency of plants where evaporators are added.

These requirements are reasonable, and it should not be a difficult problem to develop a high-grade evaporator in small units that will prove satisfactory for this service. The installation of such evaporators in these smaller boiler plants will undoubtedly result in improved plant efficiency. The elimination of trouble from alkali and soda in boiler water and the increased safety of boiler operation would amply warrant the development of such small evaporators. Many engineers believe that evaporators, along with several other new developments, will in time be regarded as regular equipment of all moderate-sized boiler plants.

The Superpower System and the Private Plant

MANY operating engineers are not in accord with the project of creating a superpower system, feeling that the plan sounds the death knell of the private plant. Those who are using intelligence in the management of the power plants under their care need not consider this phase of the subject. The superpower system will cause the shutdown of some plants, but not all.

In certain industries, notably the woolen, textile and refineries, steam is used in process work to an extent often equal to, or in excess of, the demand of the engine room. These plants can and do, as a rule, deliver a kilowatt-hour at the switchboard at a very low cost.

The point is often raised that the process steam requirements do not coincide with the engine-room steam demand. This could be corrected by using central-station power to meet that portion of the power demand which exceeds the process-steam demand but some central stations by the maximum demand rate and other factors have discouraged the use of its electric current as an auxiliary power in connection with the isolated plant. Such a plan would serve to maintain the balance between the process and engine-room steam demand, but under existing conditions might tend to lower by a slight amount the efficiency of the central-station generation due to the lowered station factor.

With the superpower system the load will tend to be equalized; in fact, this in its chief merit. Under this condition the objection to conjunctional service should be removed. The dual arrangement would increase the efficiency of the private plant and should not affect that of the superpower system, due to load diversity.

The only danger to the type of private plant under discussion is poor boiler-room operation. Where seventy per cent is possible, sixty per cent boiler efficiency is common and fifty per cent is by no means unusual. The boiler room needs attention, and with inefficiency here the isolated plant is doomed. But the engineer who uses his brains will find the superpower system will be working with and for him and not against him.

PRACTICAL IDEAS from PRACTICAL MEN

Two Steam-Pipe Kinks

I have seen several good kinks on power-plant repairs in *Power*, and I wish to contribute the two following methods which I have used several times with good results.

In plants where high steam pressures and superheat are carried and gaskets on steam pipes and valves start leaking, there often result grooved flanges, which mean replacing with new valves or sections of pipe, or resorting to some method of repair.

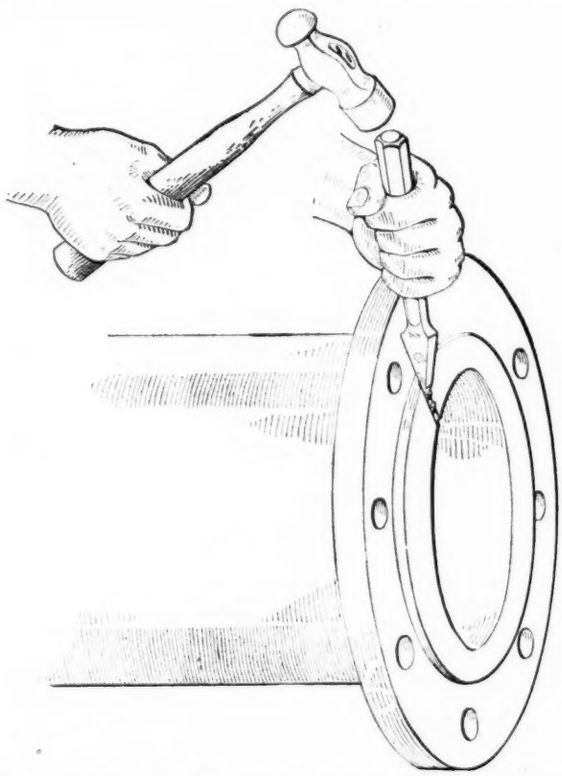


FIG. 1 DAMS ARE SET UP TO HOLD CEMENT IN PLACE

One way of repairing these flanges and also making a tight job is shown in Fig. 1. Take a cape chisel slightly wider than the groove in the flange and upset dams or burrs higher than the flange surface, making them about $\frac{3}{8}$ to $\frac{1}{2}$ in. apart. Then drawfile them down to the level of the flange surface, leaving the dams about $\frac{1}{4}$ in. wide on top. Next fill the groove between the dams with iron cement, put the gasket in place and make up the flange, and your job should be tight. The ordinary method of repairing cut flanges such as this is to fill the groove with the cement, which soon blows out for want of means of holding it in place.

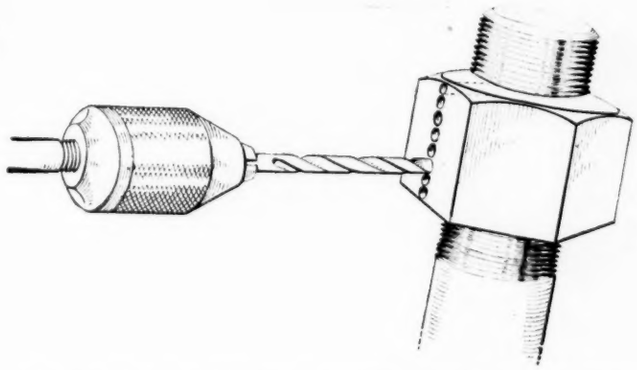


FIG. 2 DRILLING THE NUTS PREVENTS DAMAGE TO STUD

Another difficult job found in high-temperature steam-pipe work is the removing of nuts from studs on valve packing glands and valve bonnets. These usually back off a couple of threads and then seize the stud, then you either twist the stud off or find it necessary to split the nut, which usually ends in the stud being bent and the threads damaged; and if the nut is on a gland, it cannot be cut with a chisel as the gland has no solid backing.

I have found that if a small hand or motor drill is used with a $\frac{1}{4}$-in. drill or smaller, and a line of holes drilled down the side of the nut almost to the stud, as shown in Fig. 2, the nut can then be spread by placing a chisel in line with the holes and striking it a sharp blow, using something to back the nut up on the opposite side when striking the chisel. By removing the nut in this way, the studs are in good condition when your job is finished. It may be found necessary to drill both sides of the nut in some cases, the nut then being easily removed.

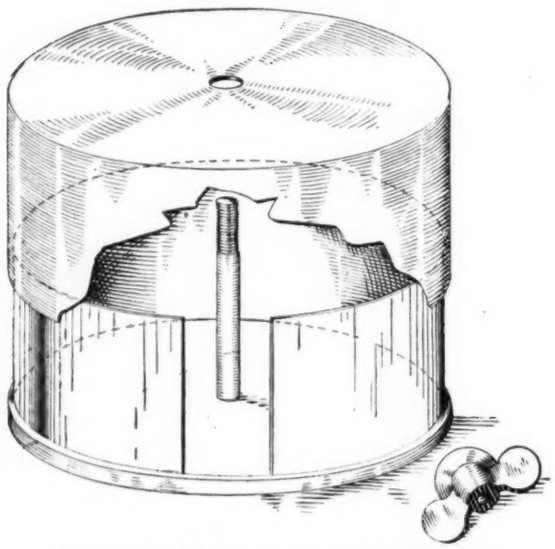
WALTER E. STEARNS.

Bridgeport, Conn.

Moisture- and Dust-Proof Chart Box

Recording gage charts should be kept dry as moisture will make the ink "crawl" and blur. To overcome this trouble and also to protect the charts from dust, the box shown in the sketch was made.

The material for making the box can be found in most plants and is easily made from light tinned sheet



SHOWS CONSTRUCTION OF CHART BOX

iron. The bolt was made of a piece of brass rod threaded and soldered to the bottom pan. A soft-rubber gasket on the bottom edge and one under the winged nut will make this a very useful chart protector in plants where dust and moisture is excessive.

Pittsburgh, Pa. J. H. SCHALEK.

Cause of Vibration in Steam Pipes

More or less vibration of the piping will inevitably attend the transmission of steam from a boiler to an engine cylinder. The vibration is due to the pulsating flow of the steam, caused by the opening and closing of the valves of the engine for admission and cutoff. But the amount of vibration in any case depends largely on the way the pipe lines are laid out and erected. Excessive and dangerous vibration of a steam pipe may generally be attributed to poor judgment in attending to these details. The pulsation of steam through a line of pipe is attended by undulations in the pressure of the steam.

Suppose a closed cylinder, Fig. 1, contains a fluid under a constant pressure and that the fluid is escaping through a quicker-closing valve on the end of a pipe bent at right angles to the cylinder. Then the tension of the outgoing fluid will progressively diminish during its passage through the pipe. Suppose the constant pressure in the cylinder is 50 lb. per sq.in. and the constant diminution of pressure in the vertical section of the escape pipe amounts to about 1 lb. per sq.in. Then the bent pipe will continue steadily in a fixed position.

Suppose now, that the gate valve be suddenly closed. Then the cylinder pressure of 50 lb. per sq.in. will be realized instantly in the vertical section of the pipe. The force of impact against the disc of the valve, due to suddenly arresting the outflow, will be transmitted to the angle in the pipe and will be expended in an effort to straighten out the pipe. The instant effect will be a straining of the vertical section of the pipe to the position toward the left, followed immediately by a return of the pipe to its original form. In other words, there will be vibration, and if the gate valve be opened and closed at short intervals, there will be a rapid series of vibrations. This is what happens in the steam pipe of an engine when the valves open and close for admission and cutoff.

An objectionable arrangement of steam piping is shown in Fig. 2. In this case the two boilers were used "week about" to supply steam to a high-speed engine. When the boiler at the left was in use, the vibration was excessive, particularly when the engine was carrying a heavy load; when the boiler at the right was in use, the vibration diminished somewhat.

This difference in the vibratory effect of the steam flowing from each boiler might be attributed to the fact that when the left-hand boiler was in service the zigzag course of the steam was in the same general direction. Thus the straightening impulse at the turns was cumulative in its effect. But when the right-hand boiler was in use, the effect of the impact against the walls of the pipe contiguous to the first and second turns from the boiler was partly neutralized by the reactions of the impacts near the third and fourth turns. Hence, the vibrations set up at the third and fourth turns counteracted in some degree the vibrations set up at the first and second turns.

To remedy the trouble, it was decided to make the turns with long-radius bends, as indicated by the dotted

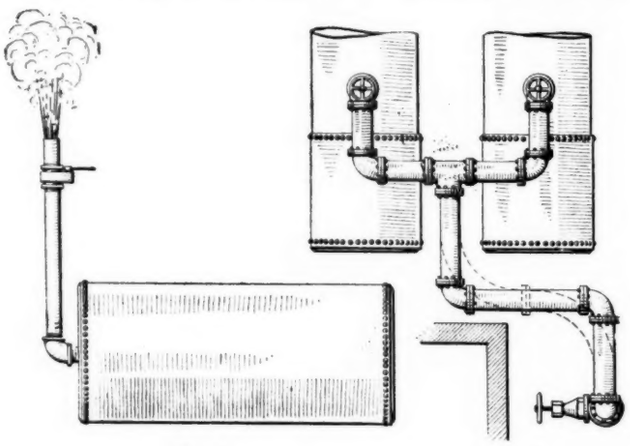


Fig. 1 Fig. 2

FIG. 1. VIBRATION IN PIPE LINE
FIG. 2. OBJECTIONABLE PIPING LAYOUT

lines. The long curved surfaces of these bends resulted in the steam striking the walls of the pipe at a more oblique angle and diminishing the vibratory effect.

Vibration of a steam line supplying an engine may be abated by installing a large receiver separator in the line near its connection with the engine. The comparatively large volume of steam in the receiver acts as a buffer in absorbing the ramming effect of the steam current when cutoff occurs. The reaction due to suddenly arresting the steam flow to the cylinder is expended in compressing the steam in the receiver, while the momentum of the current coming from the boiler is likewise dissipated. Thus the pulsating flow through the pipe is transformed into a comparatively steady flow.

A. J. DIXON.

St. Louis, Mo.

Using Potential Transformers Inverted Causes Error

Transformers may be grouped in various ways to accomplish different results. However, when dealing with instrument transformers due care should be given to the question of the effects of the grouping on the meter readings. The arrangement shown in the figure was suggested as a possibility of using a 440-volt polyphase wattmeter on a 6,600-volt three-phase circuit, when the only potential transformers available were a pair of 6,600- to 110-volt and a pair of 440- to 110-volt

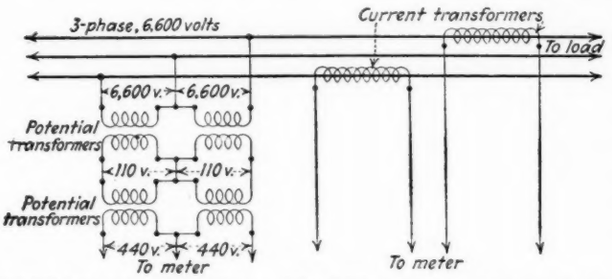


DIAGRAM OF POTENTIAL TRANSFORMER CONNECTIONS

transformers. It was proposed to step the 6,600 volts down to 110 and then step it up again to 440 volts as indicated in the diagram.

In using inverted potential transformers as in the figure, there are three sources of error, all of which tend to produce a low deflection of registration on the wattmeter or watt-hour meter. This error amounts to only about 3 per cent under the best of conditions to perhaps 25 per cent under the worst conditions, depending on the design of the transformers used.

The first error is caused by the extra load introduced by connecting the 110- to 440-volt transformer to the secondary of the 6,600- to 110-volt transformer. These latter transformers are compensated to give the correct ratio with probably a 25 to 50 volt-ampere load. In this case, however, the secondary load is considerably more than this, being the combined load of meters, and magnetizing current of the 110- to 440-volt transformer. Consequently, we may find only 105 to 109 volts across the secondary windings of the 6,600- to 110-volt transformers.

The second error is caused by making the 110-volt winding of the 110- to 440-volt transformer carry the transformer magnetizing current in addition to the meter-load current. This extra current increases the current times resistance drop in the transformer and may leave only, say, 90 to 105 volts available to magnetize the iron.

The third error is introduced by the negative compensation due to the inverted use. The actual ratio in turns is not 440 to 110, but is about 440 to 111.5, the extra 1.5 volts being lost in the windings and magnetic circuit, so under normal operation only 110 volts appears as available. Now, with inversion, the ratio becomes 111.5 to 440, so if only 90 to 105 volts is impressed on this winding, the secondary is only increased by the ratio of 111.5 to 440. In addition there is another slight error in the regulation of the transformer which reduces the final results one or two per cent more.

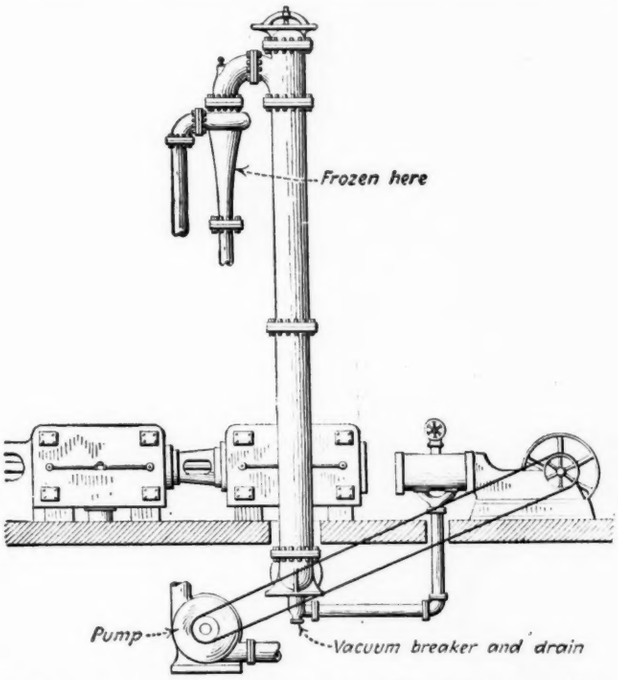
If, however, the 6,600 to 110 transformers are fairly large, and the 440 to 110 only large enough to carry the meter load (say about 25 or 50 volt-amperes capacity) then the meter and transformers may be calibrated correctly as a unit and should give just as accurate results as if it were connected directly to the 110-volt circuit.

Summit, N. J. VICTOR H. TODD.

Starting with the Injection Water Discharge Closed

Some years ago I found out what would happen when the exhaust pipe of an engine got full of water. I had a tandem-compound unit served by a barometric condenser. The water for this condenser was furnished by a rotary pump driven by a 10 x 12-in. engine, operating at 300 revolutions per minute.

I started the pump engine as usual on Monday morning with the thermometer registering 20 deg. F. In about ten minutes there was a severe bump and the pump engine stopped with water blowing from the exhaust connections. The initial cause of the trouble was found to be in the throttle of the main unit, which was of the double-beat type and leaked slightly. This leakage had worked its way through the cylinders and into the throat of the condenser, where it had frozen up tight. The pump engine exhausted into the base



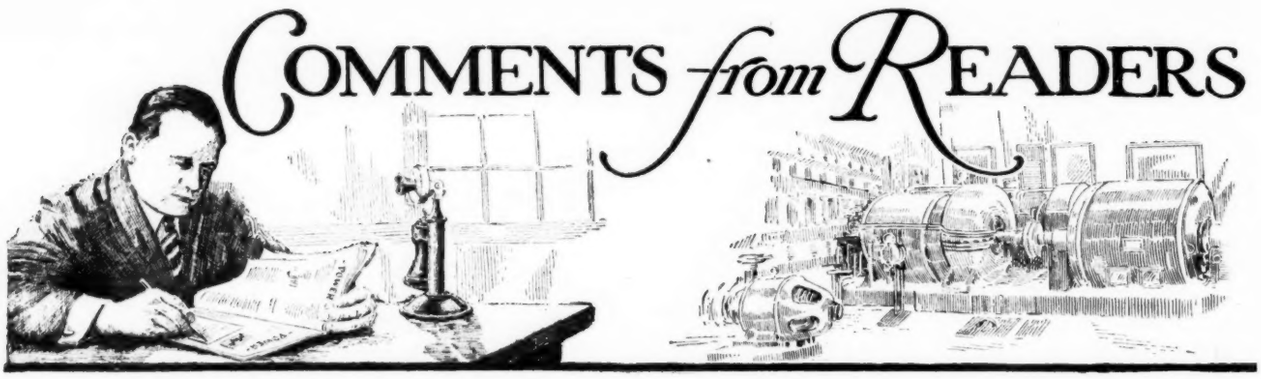
SHOWS WHERE INJECTION WATER DISCHARGE WAS FROZEN, CAUSING FLOODING OF CYLINDER

of the exhaust riser, and when the water from the pump could not follow its legitimate course to the hotwell, it backed up through the elbow and came down the large exhaust pipe into the pump-engine cylinder.

This caused the piston rod to spring a trifle, but not enough to prevent the engine from being run the full week, approximately 130 hours. The cylinder head and all bearings withstood the shock wonderfully well.

If steam will flow one way in a high-pressure line, and water of condensation in a reverse direction, what is to prevent exhaust steam flowing one way and water of condensation against it, if conditions are right?

New York City. C. W. PETERS.



Turbine-Accident Evidence Contradictory

The turbine accident described on page 387, March 7 issue of *Power*, is apparently another of those occurrences that just happened, and nobody can account for the cause positively. From reading the article it is apparent that the turbine-driven alternator and engine-driven direct-current generator could be tied together through the rotary converter as indicated in the figure. If this is the case and all machines were on the system at the time of the accident, the cause of the failure would be easily accounted for, provided there were no reverse-current relays in the system. If the direct-current generator happened to be thrown on the line at a somewhat higher voltage than the rotary, the latter would be motorized. If the rotary converter was compound wound, when motorized the current in the two field windings would be in opposition. This would cause the rotary to speed up and raise the frequency of the system, and the alternator would become a motor, taking power from the direct-current generator through the converter. This would result in an increased current hrough the converter's series winding, causing a further

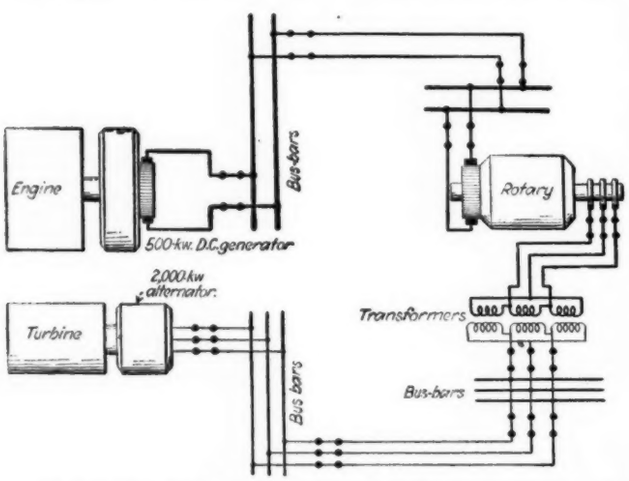


DIAGRAM OF CONNECTIONS BETWEEN DIRECT-CURRENT AND ALTERNATING-CURRENT GENERATORS

weakening of the field poles and producing a further increase in speed and frequency, which would in turn increase the speed of the alternator. This process of acceleration could all occur in a few seconds if once started.

After the turbine reached a speed to operate the emergency trip, the steam would be cut off, but the speed would continue to increase until something cut the power off from the converter. When the overspeed trip on the turbine had operated, the latch and pin of this device would continue to hammer and produce the condition found. The fact that no steam escaped from the turbine when the accident occurred shows that the steam must have been cut off, for a sufficient time before failure took place, to allow the pressure in the machine to be reduced to atmosphere or less. This being true, then the overspeed that caused failure of the turbine must have been produced from the electrical end and not the steam.

There is only one way the alternator could be overspeeded and that is by building up the frequency of the system to which it was connected, as explained in the foregoing. However, according to the published report the direct-current generator, although ready to be connected to the busbars, was not connected to the system, and if this be true, the accident could not have been caused from the electrical end. It would be interesting to know how high the speed of the rotary would have to be before its overspeed device would trip. At 13 per cent overspeed, if the rotary was motorized and supplying power to the alternators, the latter would be operating at about 4,000 r.p.m., which would increase the stresses in the turbine wheels about 30 per cent. If the steam were cut off from the turbine for any length of time, the temperature of the wheels would increase and might cause strains that would easily produce failure at 13 per cent overspeed. However, it is evident from the distortion of the fan vanes on the alternator's rotor that the speed must have been much higher.

Where the human element must be depended upon for the details in an accident, conflicting evidence may be expected. If graphic records are not available, then conjectures of what might have occurred are about the best that can be put forward. In most cases, if the evidence of those present is taken, then almost any probable cause can easily be contradicted as in this case.

Philadelphia, Pa. R. M. COFFEY.

What Charge Should Be Made for Steam?

The article in the Jan. 3 issue relating to what charge should be made for steam, is one that should be better understood by engineers who have power plants in their charge.

Some time ago I had charge of a plant and the owner, being interested in knowing what he was getting for his money, wanted a report covering the use of steam and electricity. I used the following method:

First, on securing the data the cost of the entire plant was found from the bills and contracts which covered

the installation. As the plant was installed in a part of the establishment, no charge was made for the building or its equivalent in rental.

Next all the live steam used was metered by a steam-flow meter, excepting live steam for heating. Returns from the heating system were passed through a condensation meter, also the returns from a hot-water generator. These meters gave the weight of water used for this purpose, whether of live steam or exhaust.

As I did not have a meter on the live-steam line to the engine, the water rate given by the manufacturers was used to figure the amount consumed for the generation of electric current. The boiler-feed water was measured by a meter, checking this by weighing a certain number of cubic feet each month, or more often, on platform scales, using a barrel. Usually, three or four tests gave a good average. By taking the charges from the auditor each month, which included all salaries and materials, I added the overhead, depreciation, taxes on assessed value, interest, and insurance. The result is the total monthly expenses. (This plant operated continuously.) I used the boiler feed-water meter reading as the total horsepower generated, which gave the cost per horsepower-hour or in 1,000 lb. By using the readings of the various meters in pounds per hour, the cost per horsepower-hour is divided between the departments pro rata. However, the total result never shows up to equal the input as boiler feed, due to blowing down, trapping headers, and loss from oil separators, drips, etc.

An example of obtaining the cost per 1,000 lb. of steam used is as follows:

	Pounds
Turbine	45,000
Factory	25,000
Live-steam heating	10,000
Low-pressure air	12,000
High-pressure air	1,000
Circulating water turbine	2,000
	95,000

Ninety-five thousand pounds as metered would give the approximate service that would absorb the total charge of plant. If $100 was the total cost of operation for this amount of service, it would cost $100 ÷ 95 = $1.06 per 1,000 lb. water, or

Turbine	45 × $1.06 =	$47.70
Factory	25 × 1.06 =	26.50
Steam heating	10 × 1.06 =	10.60
Low-pressure air	12 × 1.06 =	12.72
High-pressure air	1 × 1.06 =	1.06
Circulating water	2 × 1.06 =	2.12
		$100.70

Now, if credit is made to the plant for steam heat and the hot water heated, let us assume that the returns from the heating system amount to 20,000 lb. of water. Out of this take the weight of live steam, which would leave 20,000 — 10,000 = 10,000 lb. of steam as exhaust from the heating. The hot-water heater returns to the condensation meter show 6,000 lb. This added to steam heat returns shows 16,000 lb. as byproduct or credit to the steam turbine, as this exhaust steam is taken from it. The turbine being a mixed-flow unit, economy was the byword when it was installed. Now, going back to the division of costs, the turbine charge would appear as follows, with credit for exhaust steam:

TURBINE

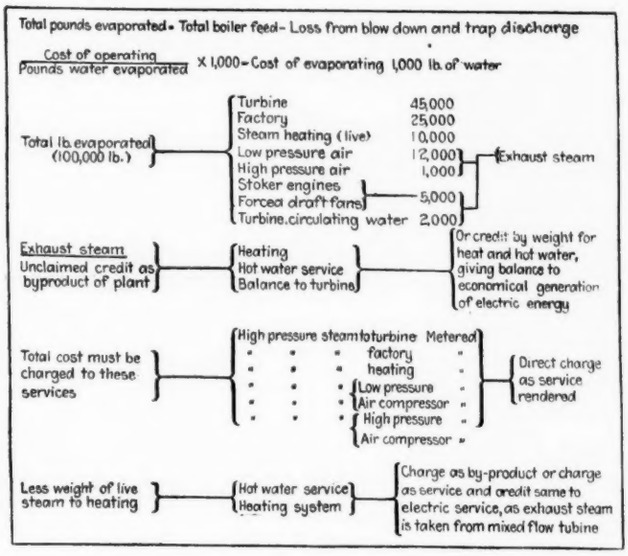
Exhaust steam	16,000 or 16 x 1.06 = $16.96
Live steam	29,000 or 20 x 1.06 = $30.74

out of which the cost per kilowatt-hour would be

$$\frac{30.74}{\text{Kw.-hr.}} = \textit{cost per Kw.-hr.}$$

Without any credit to the turbine made for exhaust-steam heating and hot-water service the cost per kilowatt-hour would be $\frac{47.70}{\text{Kw.-hr.}}$.

The method of charging power costs is shown by the following:


Total pounds evaporated - Total boiler feed - Loss from blow down and trap discharge
Cost of operating / Pounds water evaporated × 1,000 = Cost of evaporating 1,000 lb. of water
Total lb. evaporated (100,000 lb.)
Turbine 45,000
Factory 25,000
Steam heating (live) 10,000
Low pressure air 12,000
High pressure air 1,000
Stoker engines
Forced draft fans 5,000
Turbine circulating water 2,000
Exhaust steam
Exhaust steam
Unclaimed credit as byproduct of plant
Heating
Hot water service
Balance to turbine
Or credit by weight for heat and hot water, giving balance to economical generation of electric energy
Total cost must be charged to these services
High pressure steam to turbine Metered
factory
heating
Low pressure
Air compressor
High pressure
Air compressor
Direct charge as service rendered
Less weight of live steam to heating
Hot water service
Heating system
Charge as by-product or charge as service and credit same to electric service, as exhaust steam is taken from mixed flow tubine

I agree with W. A. Miller in that the returns should not be credited, as in some plants their entire use is not practical. In the plant I mentioned, the returns from one department were filtered and used for ice making.

In G. H. Lewis' proposition it would seem that he has some of the needed apparatus to obtain his charges, as his V-notch meter will give him his total boiler feed. This would give his boiler output in water rates as 30 lb. per hour. No doubt he can obtain his overhead charges from the cost of the plant and such supervising charges as apply to his plant. This added to the cost of material can be figured into the cost of 1,000 lb. of steam generated. This would give a basis to figure from.

If the steam supplied to the turbine is metered, charge to electric energy, and if the steam to the factory is metered, charge to department or to general expense, as the case may be. If he wishes to charge his steam heat as a service, he can use his condensation returns as a basis of figuring these, if it is a byproduct of his plant, the live steam should be metered by steam flow meter. His hot water can be charged for by either a steam flow meter or by the condensation meter, provided the water is heated by steam.

I think that the best way to get the steam consumption for the air compressors would be by the use of a steam-flow meter. My experience with this type of apparatus shows that the machines use more steam per horsepower or cubic foot of air, when running slow or part time, than when running at three-quarters or full load. This type of apparatus carries heavy cylinder condensation. Mr. Lewis' question, the last paragraph, would answer itself. Each machine or use to which the steam is put, should have its proper charge as these are often used in departments foreign to one another.

M. E. GUILE.

Binghamton. N. Y.

Why Good Boilers Explode

If only defective boilers ruptured, most if not all of the mystery attending explosions would disappear. The remedy would be the condemnation of those boilers found unsafe upon inspection. Unfortunately, good boilers are also susceptible to the exploding habit, and it has been claimed that there have been almost as many disasters in apparently safe boilers as in weak ones. An example of the destruction possible in a sound vessel is the explosion at the Mechanicsville plant, an account of which appeared in *Power* Nov. 29, 1921. Here was a boiler built on approved lines, of high-grade metal and apparently operated with reasonable intelligence and care. Yet, with all these factors tending toward safety and freedom from trouble, the boiler gave way after being fired up following a day of idleness.

On studying the history of explosions, it will be found that defective boilers explode at any hour and on any day. Good boilers on the other hand seem to have a preference for Monday. With the desire of arriving at an explanation that would account for this phemonenon, the following ideas are advanced.

It is quite interesting to notice the behavior of water when heated. If a vessel, Fig. 1, be partly filled with water and placed over a flame, the water temperature

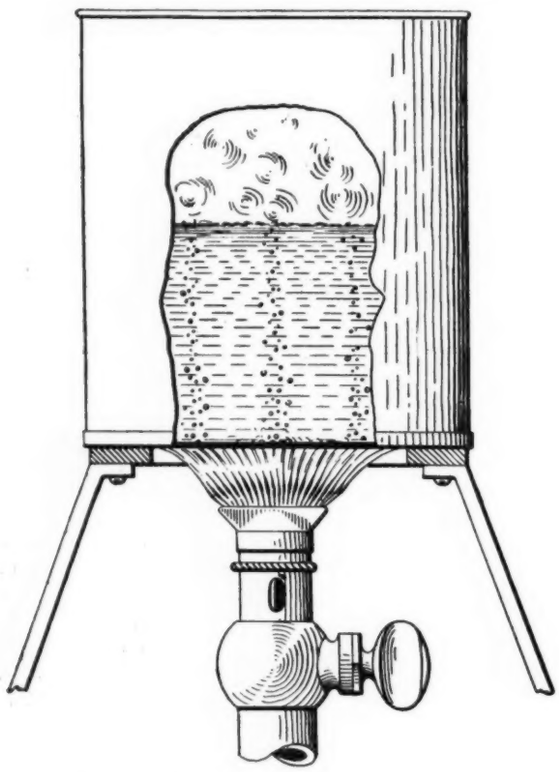


FIG. 1. ACTION OF BOILING WATER

rises. Soon small bubbles of steam appear on the bottom of the can and, detaching themselves, rise upward to the surface. It will be found that the formation of bubbles is not universal over the bottom, but is confined to definite areas even though the heating be uniform.

The answer seems to be that at these local points sediment, even though minute, has formed and small amounts of air are intermingled with the particles. Each particle of dirt and each air droplet acts as a nucleus about which a steam bubble is formed. It is true that continued heating of the vessel will finally cause the formation of steam to occur at all points in the body of water, but undoubtedly this is due to the distribution of the sediment particles and air bubbles by agitation.

If one has a glass test tube handy, an interesting experiment may be performed with little trouble. Let us take a test tube and after washing it thoroughly with sulphuric water, partly fill it with distilled water. This water is reasonably free from dirt particles, but does contain considerable air. Place the test tube over a flame and heat the water until the boiling is vigorous. Now remove from the flame and cork the mouth. After the tube and water are cool, start to reheat it, doing it very slowly. Continued heating will cause a surface evaporation as evidenced by the lowering of the water level, but no ebullition or formation of steam bubbles in the body of water takes place. A little more heating and the entire body of water seems to hurl itself toward the top and the tube explodes. This is the Mechanicsville boiler explosion in miniature.

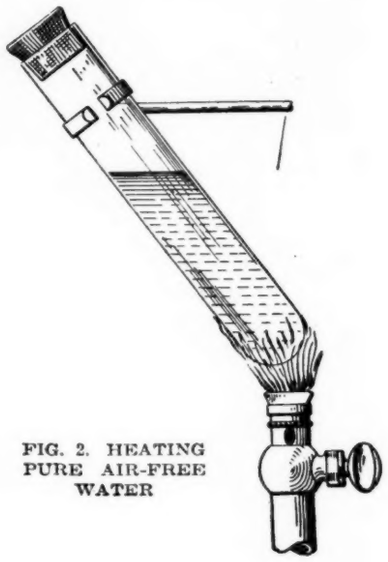


FIG. 2. HEATING PURE AIR-FREE WATER

Let us go into the details. Remember the test tube of water boiled vigorously as long as air was present to set up the initial boiling. Since no dirt particles were present to act as the nuclei after the water cooled, reheating failed to produce ebullition since no air or sediment was present to start the process. But how account for the apparent explosion? We know that the temperature of a body, say of the water in the test tube, as indicated by a thermometer, is not the exact temperature of each molecule of water, but the average temperature. The temperature is dependent on the velocity of the innumerable molecules of water, some of which are vibrating with a velocity far greater than that of others. In ordinary boiling or steaming the molecules with the greatest velocity collect about the air or dirt particles and, traveling upward, finally pass into the space above the water level. The further application of heat increases the velocity of the slower molecules, and they in turn fly into the steam space.

The high-velocity molecules may, by traveling here and there, finally reach the water surface, overcome the surface tension and drift into the steam space. The average velocity (and average temperature) of the remainder increases with the addition of heat. More and more of the high-speed molecules reach the surface and drift into the steam space, but at the same time many of the steam molecules vibrate in the water and never reach the steam space. The entire action is to cause the slow-speed molecules to speed up, and the high-speed molecule by colliding with the slower ones suffers a decrease or at least no increase in velocity. The aver-

age velocity becomes the velocity of every molecule. The result is that finally a point is reached where the entire mass, whose velocity is increasing owing to the application of heat, has a velocity equal to that of a molecule in what we term the *steam* state. The water or steam increases in volume and, rising upward, breaks the test tube by water hammer.

The Mechanicsville boiler on being shut down on Saturday was probably full of hot ebullating water which, if no fresh feed water was pumped in, was practically free of air. The sediment, usually held in suspension by the circulation, settled on the shell during Sunday and became a hard crust, even though of microscopic thickness.

Monday morning the boiler was steamed up. No air or dirt particles existed to start the formation of the first bubbles. Continued firing of the furnace raised the steam pressure by surface evaporation. Finally, the mass of water attained a uniform molecular velocity equal to that velocity we designate as steam. The formation of this enormous mass of steam bubbles rose, struck the top shell with great force, and the shell gave way.

Jersey City, N. J. J. CASSIDAY.

Compensating Pressure Gages for Error Due to Water Column

In the Dec. 27, 1921, issue W. J. Meinzer gave several plans of connecting low-pressure gages so as to get a correct and reliable indication whether the gage is placed above or below the pipe line.

In Fig. 1, with the gage below the line, the connecting pipe is shown entering the bottom of the main. This would act as a drain for condensation in the bottom of

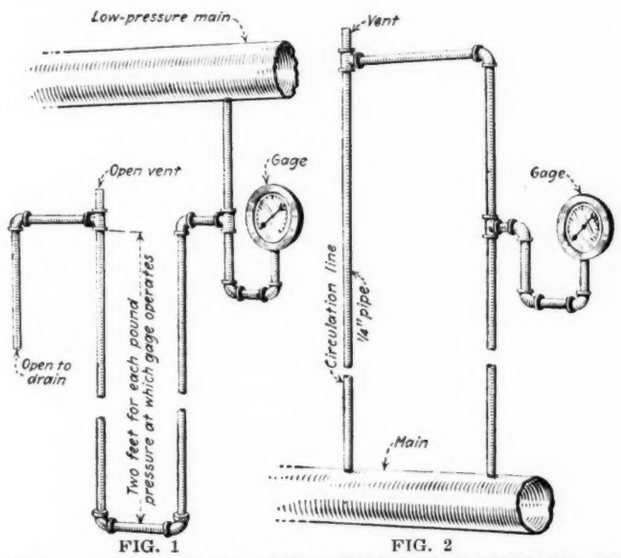


FIG. 1 FIG. 2

FIGS. 1 AND 2. GAGE CONNECTIONS RECOMMENDED BY MR. MEINZER

the pipe and, being usually of ¼-in. size, might easily be filled to capacity with condensation passing to the drain. Under this condition the gage will show an incorrect pressure. A better way is to tap in the side or top of the pipe.

In Fig. 2, with gage above the line, is shown a vent at the top of the loop. This is unnecessary with steam, as any air in the pipes will be carried away by the circulation of steam induced in the loop. The modern vapor system of steam heating is a good example of this.

From Mr. Meinzer's article I presume that he intends it for very low pressure steam lines where the pressure due to the column of water would introduce considerable error in the gage reading which could not be compensated. It is evident that these methods would not be required with water, for if we substitute water for

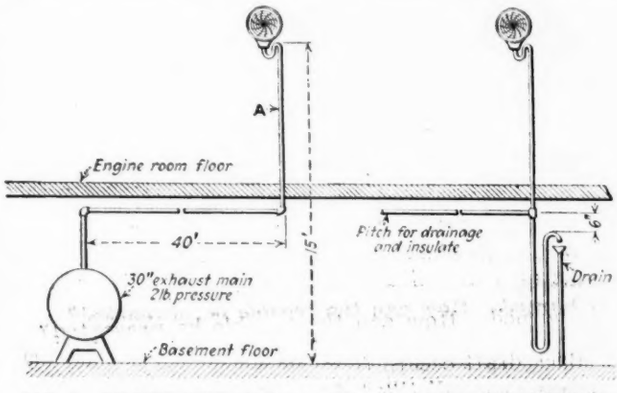


FIG. 3. SHOWS THE USUAL METHOD OF GAGE CONNECTION

FIG. 4. THE PRINCIPLES SHOWN IN FIGS. 1 AND 2 COMBINED

steam in Fig. 3, there will be required about $15 \times 0.434 = 6.51$ lb. pressure in the 30-in. main to force water to the level of the gage, and the gage would show no pressure until the water was forced higher than this.

I notice in the Jan. 31 issue that J. T. West takes exception to these plans and states that the "arrangement would not be applicable to steam at any pressure, and only on water systems of small pressure such as seldom found."

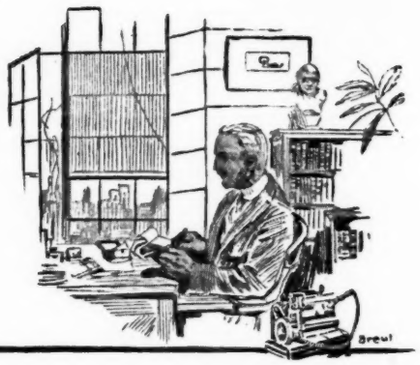
I cannot agree with Mr. West's statements. The plans proposed by Mr. Meinzer with changes noted are feasible and reliable where they can be used. I can say from experience that they are a simple and reliable means of obtaining remote indications of pressure in mains carrying low-pressure steam of from a slight vacuum to six pounds pressure as is used in exhaust-steam heating systems. Fig. 4 is a method combining the principles of the other two and is more easily installed where the horizontal distances are great. This is in successful operation in a plant, and the recording gage indicates accurately when compared with a mercury column tapped in the side of the main.

Mr. West's method of adjusting the gage pointer to compensate for the water column is the usual custom where it will work. How would he adjust his gage for the conditions shown in Fig. 3? This scheme was tried and found wanting. Condensation collected in the pipe *A* and would cause the gage to indicate a vacuum when there was two pounds pressure in the exhaust main. If the gage line was blown out, the gage would indicate the correct pressure for a short time or until pipe *A* again filled. This was changed to the plan shown in Fig. 4, with the results noted.

Objection is also taken to the headroom required by these schemes, but that difficulty solves itself. In basements where headroom is lacking, the pipe lines may usually be touched by the hand while standing on the floor, and a gage connected in the side of the pipe will be at a convenient height and reading distance. It is in cases where the gage is at a distance horizontally or on the floor above, that the plans illustrated are an improvement. JOHN A. GRAHAM.

Pittsburgh, Pa.

QUESTIONS AND ANSWERS



Back Draft in Boiler Furnace

We are considerably troubled with explosions or back draft of a hand-fired boiler furnace in which soft coal is burned. How can the trouble be prevented?

G. N. R.

Back draft occurs from sudden combustion of hydrocarbon gases distilled from the coal with insufficient supply of oxygen to support combustion of the gases as rapidly as they are liberated from the fuel. Hence backfiring is likely to occur from firing too heavily at a time, and more especially when there is a poor draft. The remedy is to carry thinner fires with light charges of fuel and leave some part of the fire uncovered, so there will be a better air supply through the grates and ignition of the combustible gases as rapidly as they are formed.

An Agitator Pipe Freezer

In our raw-water ice plant the pipes that carry the agitating air into the ice cans often freeze up. What is the cause and remedy? D. F. C.

The amount of water vapor contained in a given volume depends on the temperature. The amount of the vapor held in suspense at 60 deg. F. is much greater than at 20 deg. F. If the air is cooled, it cannot carry as much vapor as before and some of the vapor will condense. An example of this is the familiar dew which settles on the grass on a cool night following a warm day.

In the raw-water plant, if the air passing along the agitator pipe is warm, a large amount of water vapor is carried along with the air. At the outlet in the can when the water is below freezing, a greater part of the water vapor condenses and, settling in the air pipe, freezes.

The remedy is to cool the agitating air by means of a dehumidifier before allowing it to enter the ice can.

Live Steam Feed-Water Heaters

What benefit is to be derived from use of a live-steam feed-water heater? D. M.

Live-steam feed-water heaters are mainly beneficial as purifiers of feed waters containing carbonate of lime and sulphate of lime, as those substances, when present, are precipitated out of the water when it is sufficiently heated. By employing for that purpose live steam under boiler pressure and sufficient heating surface, the feed water may be heated nearly to the same temperature as the water in the boiler from which the steam is supplied to the heater, and thus obtain precipitation of the impurities in the heater from which they can be removed in place of having them form a troublesome scale by precipitation after the water has been fed to the boiler.

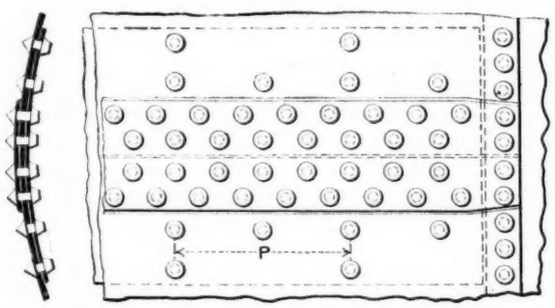
Another advantage of live-steam feed-water heaters is that by delivery of feed water of higher temperature the life of the boiler is prolonged from less variation of expansion and contraction of the boiler material than when the feed-water temperature is not raised so nearly to that of the water in the boiler.

Efficiency of Butt and Double-Strap Joint Quadruple Riveted

What would be the efficiency of a quadruple-riveted butt and double-strap joint in which the tensile strength of plate is 55,000 lb. per sq.in.; thickness of plate, $\frac{1}{2}$ in.; thickness of butt strap, $\frac{7}{16}$ in.; pitch of rivets in outer row, 14 in.; diameter of rivet holes, $\frac{7}{8}$ in.?

R. B.

Having tensile strength of plate = 55,000; thickness of plate $\frac{1}{2}$ = 0.5 in.; thickness of butt straps $\frac{7}{16}$ = 0.4375 in.; pitch of rivets equal to P in the sketch = 14 in.; diameter of rivet holes $\frac{7}{8}$ = 0.875 in.; cross-sectional area of a rivet = $(0.875)^2 \times 0.7854$ = 0.6013 sq.in.; and assuming strength of a rivet in single shear = 44,000 lb. per sq.in., in double shear 88,000 lb. per sq.in.,



BUTT AND DOUBLE-STRAP JOINT QUADRUPLE RIVETED

and the crushing strength of plate = 95,000 lb. per sq.in., then per unit of pitch P shown in the sketch:

(1) Strength of solid plate = $14 \times 0.5 \times 55{,}000$ = 385,000 lb.

(2) Strength of plate between rivet holes in the outer row = $(14 - 0.875)\ 0.5 \times 55{,}000$ = 360,937 lb.

(3) Shearing strength of eight rivets in double shear, plus the shearing strength of three rivets in single shear = $(8 \times 88{,}000 \times 0.6013) + (3 \times 44{,}000 \times 0.6013)$ = 502,686 lb.

(4) Strength of plate between rivet holes in the second row, plus the shearing strength of one rivet in single shear in the outer row = $[(14 - 2 \times 0.875)\ 0.5 \times 55{,}000] + (1 \times 44{,}000 \times 0.6013)$ = 363,332 lb.

(5) Strength of plate between rivet holes in the third row, plus the shearing strength of two rivets in the second row in single shear and one rivet in single shear in the outer row = [(14 — 4 × 0.875) 0.5 × 55,000] + (3 × 44,000 × 0.6013) = 368,121 lb.

(6) Strength of plate between rivet holes in the second row, plus the crushing strength of butt strap in front of one rivet in the outer row = [(14 — 2 × 0.875) 0.5 × 55,000] + (0.875 × 0.4375 × 95,000) = 373,242 lb.

(7) Strength of plate between rivet holes in the third row, plus the crushing strength of butt strap in front of two rivets in the second row and one rivet in the outer row = [(14 — 4 × 0.875) 0.5 × 55,000] + (3 × 0.875 × 0.4375 × 95,000) = 397,851 lb.

(8) Crushing strength of plate in front of eight rivets, plus the crushing strength of butt strap in front of three rivets = (8 × 0.875 × 0.5 × 95,000) + (3 × 0.875 × 0.4375 × 95,000 = 441,601 lb.

(9) Crushing strength of plate in front of eight rivets, plus the shearing strength of two rivets in the second row and one rivet in the outer row, in single shear = (8 × 0.875 × 0.5 × 95,000) + (3 × 44,000 × 0.6013) = 411,871 lb.

The least strength for a unit length of joint, *P* in the figure, is derived from consideration (2), namely, 360,937 lb., and as according to (1) the strength of the solid plate for the same unit length of joint would be 385,000 lb., the efficiency of the joint would be 360,937 × 100 ÷ 385,000 = 93.7 per cent.

Length of Pipe Threads to Enter Fittings

In ordering ¼ to 3 in. wrought iron or steel pipe, what allowance should be made for length of threaded ends to be entered into the fittings? W. F. L.

When pipe and fittings are provided with standard screw threads, the lengths to be allowed for each end to be screwed into the fitting, are as follows:

For pipe of nominal ¼ in. inside dia. allow 0.39 or about ⅜ in.; ¾ in. pipe, 0.4 or about 13/32 in.; 1 in. pipe, 0.51 or about ½ in; 1¼ pipe, 0.54 or about 9/16 in.; 1½ in. pipe, 0.55 or about 9/16 in.; 2 in. pipe, 0.58 or about 19/32 in.; 2½ in. pipe, 0.89 or about ⅞ in.; and for 3 in. pipe, 0.95 or about ⅞ in.

Cylinder Cooling and Re-evaporation

What is cylinder re-evaporation and why is its occurrence associated with poor cylinder economy. M. S. P.

The walls of an engine cylinder are cooled by radiation and by the comparatively low temperature of the exhaust steam, and when steam is admitted from the boiler, part of it condenses. The latent heat of that portion of the entering steam that is condensed is employed by raising the temperature of the cylinder walls nearly to the temperature corresponding to the pressure. The water formed by the process of condensation is deposited on the walls of the cylinder in the form of a thin film. This continues after cutoff takes place until the steam pressure and corresponding temperature have become reduced by expansion of the steam down to a pressure at which its temperature is about the same as the temperature of the cylinder walls. Then, upon further lowering of the steam pressure from further expansion, the water in the cylinder is re-evaporated and the steam thus formed in the cylinder during the latter part of the stroke prevents the pressure from falling as low as it would without the re-evaporation. As a result the expansion line of an indicator diagram from the point where re-evaporation begins may be higher than it would be without the re-evaporation.

Referring to the figure, suppose *ABCDE* to be an actual indicator diagram with cutoff at *B*. Assuming a zero clearance volume, the volume of steam in the cylinder at cutoff is the volume displaced by the piston in movement from *A* to *B*. But on account of cylinder condensation during admission, the actual volume of steam admitted from the boiler is greater. Suppose this additional volume to be a cylinder volume represented by the additional piston displacement from *B* to *F*. Then by adiabatic expansion—that is, with neither gain nor loss of heat excepting the heat converted into work—an expansion curve like *EG* would be realized, whose average pressure would be more than that of *BC*. If there had been no re-evaporation to raise the average pressure after cutoff at *B*, adiabatic expansion from *B* would have proceeded along a lower curve like *BH* of less average pressure than the curve of the actual dia-

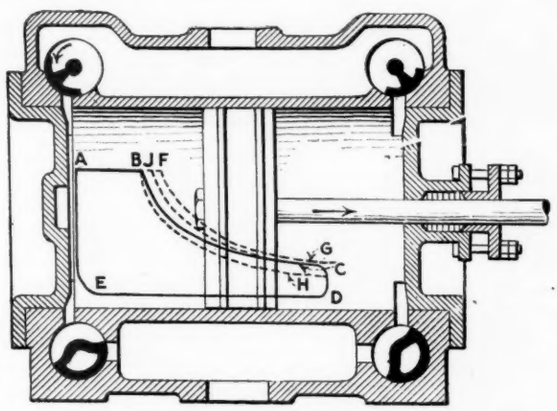


DIAGRAM ILLUSTRATING CYLINDER COOLING AND RE-EVAPORATION

gram; but the fact that *BC* is higher than *BH* shows that heat for re-evaporation of water in the cylinder must have been received. By passing an adiabatic *CJ* through *C*, it will be found that without gain or loss of heat an expansion curve like *JC* would have been necessary to pass through *C* and would have required a volume of steam to be admitted from the boiler at least equal to the piston displacement *A* to *J*.

But the average pressure of the actual diagram *BC* that is obtained for the quantity of steam represented by the displacement *AJ* is less than the theoretical average that should have been obtained, going to show that the work realized from re-evaporation is less than would have been developed without cylinder cooling and the incident re-evaporation.

In this connection it is to be noted that an average pressure higher than the average pressure of an adiabatic through *B*, or an average pressure lower than that of an adiabatic through *C* is indicative of a loss from cylinder cooling which is not replaced by a gain from re-evaporation.

[Correspondents sending us inquiries should sign their communications with full names and post office addresses. This is necessary to guarantee the good faith of the communications and for the inquiries to receive attention.—Editor.]

Disastrous Air-Tank Explosion

SEVEN dead and twenty-one injured is the toll of an explosion of a compressed-air tank at the shops of the Kansas City (Mo.) Railways on the morning of March 7. The tank that exploded was 5 ft. in diameter by 20 ft., was of $\frac{3}{8}$-in. steel and carried, normally, 110 lb. pressure. It was equipped with a pressure gage, safety valve and an unloader, the last operating automatically to shut off the compressor.

The tank and compressor were in a room by themselves adjacent to the machine shop, but separated from it by a brick wall. The second floor of a two-story section of the

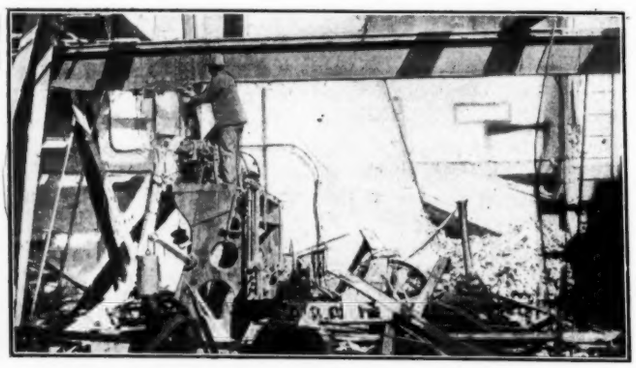


FIG. 1. SHOWS DEBRIS WITHIN MACHINE SHOP

building contiguous to the tankroom was occupied by offices, but fortunately, nobody was in these offices at the time.

Although the compressor equipment was arranged for automatic operation, an attendant was stationed in the compressor room to guard against suspension of air service. This attendant had started the compressor, as usual, when the shop opened at 7.15 a.m., and the explosion took place eight minutes later. He was killed, and the other fatalities and injuries were among those in the adjacent machine shop.

The compressor equipment had been installed about ten years ago, but had been completely overhauled about three months previous to the accident. Moreover, it had passed the usual routine state inspection within a month. All the fittings were destroyed except the unloader valve, which was found in workable condition after the explosion. Property damage was estimated to be about $20,000.

Within two hours after the accident tarpaulins had been spread over the roofs, car compressors had been built up in series to provide air for replacing the service of the destroyed tank and the shop was again in operation.

That an ample margin of safety was provided with the normal pressure may be shown by simple calculation,

$$p = \frac{T.S. \times t \times E}{R \times F.S.}$$

where

p = Allowable working pressure
$T.S.$ = Tensile strength of steel
t = Thickness of plate
E = Efficiency of longitudinal joint
R = Inside radius of shell
$F.S.$ = Factor of safety.

Assume $T.S.$ to be 55,000 lb. per sq.in. and E to be 65 per cent; p is 110 lb. gage; $t = \frac{3}{8}$ in.; and $R = 30$ in. Then

$$110 = \frac{55{,}000 \times \frac{3}{8} \times 0.65}{30 \times F.S.}, \text{ and}$$

$$F.S. = \frac{55{,}000 \times \frac{3}{8} \times 0.65}{30 \times 110} = 4.$$

The foregoing assumptions were conservatively taken, and it is possible that the designed factor of safety was even greater. Whether there was any defect in the material has not been disclosed. Neither has it been indicated at this writing whether there were any traces of oil accumulation such as might be responsible for an explosion.

FIG 2. PART OF MACHINE SHOP AND CORNER OF ADJACENT TWO-STORY BUILDING AS THEY APPEARED SHORTLY AFTER THE EXPLOSION

Recent Court Decisions

By A. L. H. Street

Warranting Engine Power

In the case of St. Marys Machine Co. vs. Cook, 218 "Southwestern Reporter," 733, the Kentucky Court of Appeals holds that where an engine is sold for installation in a manufacturing establishment, under a warranty of its power, the buyer is entitled to recover damages on the basis of loss of profits where the engine fails to pull up to the warranty. The court says:

Profits which the purchaser could have realized, had the article purchased measured up to the requirements of the contract, are recoverable in suits of this kind, since their loss is regarded as a proximate result of the breach of the contract, and they are regarded as being within the contemplation of the parties at the time of entering into the contract.

But the court distinctly holds that there must be clear proof of such loss, directly traceable to the breach of warranty before recovery can be sustained under this head.

Duty to Keep Power Plant in Safe Condition

The decision of the Vermont Supreme Court in the case of Coburn vs. Village of Swanton, 109 "Atlantic Reporter," 854, gives a general view on the legal obligation of the operator of a power plant to guard against injury to persons coming on the premises without permission.

The defendant, the Village of Swanton, operated an electric-power plant, and a man named Barr was employed as night engineer. He engaged the plaintiff to bring his breakfast to him every morning. On one occasion, while doing this, plaintiff was injured on account of an uninsulated transmission wire claimed to have been negligently maintained in a dangerous condition.

Disposing of plaintiff's suit to recover damages, the Supreme Court said in the course of its opinion:

It is a well-known principle that before liability attaches, for negligence, a duty must arise—a duty on the part of the party charged toward the party injured. . . .

The main question is whether it appears from the declaration that the plaintiff was, at the time of the injury, at the place where the accident occurred by the invitation of the defendant, express or implied—whether he was there as an invitee, or merely as a licensee. . . . Because, "as a general rule," says Thompson in his "Commentaries on the Law of Negligence (Vol. 1, p. 946), "the owner of private grounds is under no obligation to keep them in a safe condition for the benefit of trespassers, intruders, idlers, bare licensees, or others who go upon them, not by invitation, express or implied, but for their own purposes, their pleasure, or to gratify their curiosity, however innocent or laudable their purpose may be." . . . And the rule applies with equal force to children and adults.

The Court pointed out examples of the application of this principle, in which a recovery has been denied: where one was injured while on the defendant's premises, by permission, soliciting insurance from the latter's employees; where the person injured was on the defendant's premises to deliver a message, which had no connection with the business, to one of the latter's employees; where the plaintiff, a student, with others, by defendant's permission, was inspecting its power house; and many other similar cases.

And the reason is that to give a person the standing of an invitee it must appear that his purpose, when he entered the premises, was one of interest or advantage to the owner or occupant. . . .

In the case before us, when the plaintiff entered the defendant's power house, was his purpose one of interest or advantage to the defendant, or was it the benefit the plaintiff was to derive from fulfilling his agreement with Barr?

The allegations fail to show that he was there for the former purpose. . . .

The plaintiff argues that the allegations that the power house was a dangerous place and that Barr at the time of the injury had full charge and supervision thereof, show of necessity that he had authority to invite the plaintiff to go there. This depends upon what the plaintiff was invited there for. If it was for a purpose incident to, or in the furtherance of, the defendant's business, this would undoubtedly be so; but if Barr invited him there for some purpose personal to himself, and in no sense connected with the express or implied authority conferred upon him by the defendant, it could not be said to come within the scope of his employment, and for injuries resulting therefrom the defendant would not be liable.

Predicting Turbine Vibrations from Small Models

Under the heading "Vibrations of a Spinning Disc," the Feb. 24, 1922, issue of the British journal *Engineering* brings together some facts and theories of interest to those who are seeking a remedy for the vibration of turbine discs. The following abstract covers some of the principal points of this paper:

Investigations indicate that most turbine failures are due to the vibration of the wheel. It is strongly suspected that this vibration arises, in many cases, from some outside source which happens to be vibrating in synchronism with the natural period of certain turbine wheels. In fact, with the turbine at rest and the top of the casing removed, it is frequently found to be the case that some of the wheels are vibrating appreciably, due to outside disturbances. It is not to be expected that the same disturbance would vibrate the same wheel if it were rotating. It might very well vibrate some other wheel instead, since the period of vibration of a rotating disc differs from that of a stationary disc. This is due to the fact that the rotating disc not only has its natural elasticity, but is also under tension, due to the centrifugal forces.

Some experiments have been made with rotating flat discs of rubber, but the results can hardly be applied to turbine wheels without qualification, because rubber wheels are so pliable as to be considerably affected by the adjacent air. Moreover, turbine wheels are not ordinarily discs of uniform thickness, but are thicker near the center. This greatly complicates the problem. In fact, it becomes so difficult that a general mathematical solution is practically unattainable, while even an arithmetical solution for a given design is far from easy.

Another method of attack that promises practical results is to run actual tests with a model and apply the results to the full-sized apparatus. It is, of course, a well-known scientific fact that the results obtained from models cannot be applied blindly to full-sized machines. They can, however, be applied by the use of proper factors, where the experimenter is acquainted with the laws governing the relation between the size, rotating speed and period of vibration.

A recently published paper[1] on disc vibrations, by Prof. H. Lamb, F.R.S., and R. V. Southwell, contains some conclusions of great interest. For example, if the vibration frequencies due to centrifugal force alone, and to the elastic forces alone, are represented by the two legs of a right angle, the hypothenuse will represent the frequency due to their combined effect. The investigators also found, for wheels of a given shape and material, that the frequency due to the centrifugal effect was independent of the size and varied in direct proportion to the r.p.m., while the frequency due to the elastic forces varied inversely with the wheel diameter.

This knowledge makes it possible to operate a model in such a way as to predict how the full-sized machine will vibrate under a given set of conditions. For example, a quarter-sized model (same proportions and material as the full-sized machine) running at 4,000 r.p.m. without vibration (or a one-third-sized model at 3,000 r.p.m.) indicates that the full-sized machine will run smoothly at 1,000 r.p.m.

Representative Hayden, of Arizona, has introduced a bill authorizing 10-year permits for development of electric power on Government irrigation projects, with 50-year permits on the Rio Grande project in Texas and New Mexico and on the Salt River project in Arizona.

[1]Section A, Vol. 99, page 272, Proceedings of the Royal Society (Great Britain).

News in the Field of Power

Legal Delay Predicted on Muscle Shoals Project

It would take years to straighten out the legal entanglements around the Government's Muscle Shoals property before it could be turned over to Henry Ford with a clear title, Chairman Kahn of the House Military Committee said recently to W. B. Mayo, Ford's representative. Sentiment among the committee members seemed to be that it would be practically impossible to accept the Ford offer, because of the options on the Warrior Steam Plant and Nitrate Plant No. 2, held respectively by the Alabama Power Co. and he Air Nitrates Corporation. Attorneys for these companies have told Mr. Kahn that they would insist upon enforcing these options in case of an effort to sell the property to others.

On the other hand, the Judge Advocate General's office has given an opinion to the effect that the Government is not legally bound by these options, because Congress alone has the right to dispose of Government property, and the options were given without the consent of Congress.

Although Mr. Ford has refused to change his offer to a 50-year instead of a 100-year lease, he has made three other changes that were favored by the committee. He has agreed to capitalize the company that he would create at not less than $10,000,000 as a safeguard to the Government's interests. He has agreed also to manufacture "commercial fertilizers" rather than nitrates and "other compounds," and to arrange for delivery of the fertilizer direct to the consumer.

A recent development was the announcement that George W. Goethals, builder of the Panama Canal, will handle the work at Muscle Shoals if the offer of Frederick E. Engstrum is accepted.

Chairman Norris of the Senate Agriculture Committee has suggested that the project be turned over to a government corporation for operation by it. Chairman Kahn of the House Military Affairs Committee, however, opposed the proposition sharply, saying that he is "strongly against Government operation of any project that can be run by private enterprise." He wants a Government commission, including representatives of the Treasury, Agriculture and War Departments, to be given the power to lease or sell the Muscle Shoals properties, saying that such a method "is the one way of avoiding a long contested court action, which is inevitable if we favor any of the proposals at present before Congress."

The sentiment of the South was shown at a mass meeting of 3,000 people March 12 at Atlanta, Ga., where a resolution endorsing the Ford offer was passed unanimously. Ex-Governor Emmett O'Neal, the principal speaker, made a heated attack upon the Alabama Power Co., declaring that it had entirely too powerful an influence among members of the Senate and the House of Representatives.

Hoover Declines Offer To Run Philadelphia Fair

Some time ago it was reported that Herbert Hoover, Secretary of Commerce, had been offered the directorship of the Sesqui-Centennial Exposition that is being planned for 1926 in Philadelphia in celebration of the 150th anniversary of American Independence, and he has now written to Mayor Moore, of Philadelphia, definitely declining the offer. The position would have lasted for five years and would have paid Mr. Hoover $50,000 a year.

The reason given by the Secretary of Commerce for refusing so handsome an offer was that he has started a job that he wants to finish, in the reorganization of the Department of Commerce. President Harding agreed with him, he said, that he should continue the work he has begun.

Philadelphians have some reason for gratification, however, in the hearty support of their undertaking expressed by Mr. Hoover in these words:

> I wish to express appreciation of the great honor of this suggestion of the people of Philadelphia. . . . While I do not feel that I should undertake this service, I am deeply interested in the success of the effort being made by Philadelphia, and you can depend unqualifiedly upon my support and the support of this department in every possible contribution we can make to its success. I believe that Philadelphia is projecting a very great contribution to national progress.

Oregon and Mexico the Ends of New Power Line

The longest interconnected power transmission system in the world—from northern Oregon to the Mexican border—will be a reality when the California-Oregon Power Co. has finished a high-tension transmission line from its Prospect plant to Eugene, Ore., where the line will connect with the transmission line of the Mountain States Power Co.

The company has contracted to build this line, and to supply the Mountain States Power Co. for a period of thirty years. Preliminary work on the project is already under way. It is estimated that a year will be required for completion.

The new line will be 115 miles long, with a capacity of 25,000 horsepower. Although designed for 110,000-volt service, it will be operated at first at 66,000 volts. It will pass through the Rogue River and Umpque Valleys into the upper Willamette Valley.

F. A. E. S. Executive Board Meets in Chicago

The Executive Board of American Engineering Council, which is composed of representatives of the Federated American Engineering Societies, held a meeting in Chicago, March 10, at which the president, Mortimer E. Cooley, reported encouraging results from his recent swing around the circle through the South and Southwest. President Cooley started his trip in St. Louis and finished it in Louisville, visiting many other cities on the way. He reported that in all of them engineers are enthusiastically in sympathy with the ideals of the Federation and are helping greatly to widen its influence and work for its success. The executive secretary, L. W. Wallace, also spoke encouragingly, saying that the idea of engineering federation is meeting with favor, not only in this but in foreign countries.

In line with that thought the general question of international engineering federation was discussed at length, particularly the question as to whether it would be constitutional to admit the Engineering Institute of Canada to membership in the Federation, in case it should make application. It was reported that progress in engineering federation had been made in England, Canada, Australia, Sweden, France and Italy. As a result of the discussion a proposal put forward by E. S. Carman, last year's president of the A. S. M. E., was accepted. It provided for a committee "to consider and report upon the affiliation of other engineering organizations than those within the United States with the F. A. E. S."

There was a lively discussion over a resolution presented by Philip N. Moore, of St. Louis, providing "that the president of the F. A. E. S. be authorized to offer the Secretary of War the service of a committee of disinterested distinguished and skillful engineers, to be selected by a committee of its Executive Board, for the purpose of making a thorough investigation of the geological, engineering and manufacturing possibilities of the Muscle Shoals power project; this committee to serve without compensation, save for necessary expense." The resolution, however, was not approved.

Upon the advice of the Committee on Employment Service the Board voted to discharge the committee, and instructed the president to appoint a committee to consider the question of employment and report to the next meeting.

It was recommended by the Committee on Procedure to hold the next meeting in Pittsburgh the latter part of May, and the following meeting in Boston or New York, in September or October.

New Publications

Engineering Foundation's Activities. Published by Engineering Foundation, 29 West 39th St., New York City. No charge.

This is the seventh annual report of Foundation's activities in research in various branches of engineering, and contains also an abridged report of the investigation of the fatigue of metals at the University of Illinois, which was made possible by a large contribution from the Foundation.

Engineers' License Laws. Compiled by the American Association of Engineers, 63 East Adams St., Chicago, Ill. Paper; 6 x 9 in.; 136 pages. Price, 50c.

This pamphlet, which is just off the press, contains exact copies of the sixteen all-inclusive laws that are now in force for the registration of professional engineers in the various states. These sixteen states are: Arizona, Colorado, Florida, Indiana, Iowa, Louisiana, Michigan, Minnesota, New Jersey, New York, North Carolina, Oregon, Pennsylvania, Tennessee, Virginia, West Virginia. The main points of the partially inclusive laws in California, Idaho, Illinois and Wyoming are also given.

Coal Manual, By F. R. Wadleigh, head of the Fuel Department, United States Bureau of Foreign and Domestic Commerce. Published by National Coal Mining News, 834 Union Trust Bldg., Cincinnati, Ohio. Cloth or leather; 4½ x 6 in.; 184 pages. Price, cloth, $2.50; leather, $3.50.

The aim of this handy little volume is to give accurate elementary knowledge about the origin, structure, chemistry and uses of coal in non-technical language. Coal mining is not included. Instructions are given for taking samples and making analyses. It is written particularly for those who have charge of specifying and buying coal, but it is full of information that should be valuable and easily understandable to anyone having to do with coal.

Electric-Arc Welding. By E. Wanamaker and H. R. Pennington. Published by Simmons-Boardman Publishing Co., New York, 1921. Cloth; 6 x 9 in.; 254 pages; 167 illustrations. Price, $4.

This book is confined almost exclusively to autogenous electric-arc welding and is based largely on an extensive series of articles by the same authors, which was published in *The Railway Electrical Engineer.* This material has been revised, enlarged and brought up to date. The work is divided into eleven chapters: Evolution of welding processes; equipment for arc welding; installation of arc welding equipment—welding accessories; electric-arc welding principles; training operators; carbon-arc welding and cutting; electrode materials for metallic arc welding; preparing work for electric-arc welding; iron, steel and non-ferrous metal welding; application of arc welding to railroad and structural engineering; miscellaneous notes and arc-welding data.

The book is intended to serve the needs of those who have to deal with the practical problems of arc welding, therefore the phenomena of arc welding and the metallurgy of welding have not been treated of. Although the treatment tends particularly toward railway work, all those interested in the practical application of electric arc welding to other fields should find much in this book to serve their purpose.

Regelung der Kraftmaschinen. By Max Toole. The third edition of Professor Max Toole's work on "Governors for Prime Movers" in German. Published by Julius Springer, Berlin, 1921; 890 pages and over 500 illustrations and charts.

REVIEWED BY L. C. LOEWENSTEIN

The material in the first two editions remains unabridged and about two hundred pages have been added. The new material covers chiefly the following features:

A revision of the strength calculations of flywheels, taking into account the strengthening effect of the flywheel arms.

An investigation of the proper methods for balancing locomotive drivers so as to produce uniform rail pressure. The author investigates the secondary forces produced in attempting to balance the reciprocating and oscillating parts of locomotive engines and shows that the usual weights added to the drivers for securing mechanical balance have neglected these secondary forces which may be of considerable magnitude in the case of high-speed locomotives.

An investigation of the influence on governing produced by torsional oscillations of the driving shaft as in the case of gas or oil engines.

The investigation of torsional oscillations of shafts is extended in its application to the oscillations occurring in the driving shafts for submarines and airplanes.

A number of the newer governor constructions of German manufacture are added.

The book as a whole is well adapted for use as a text book for those students that have a thorough mathematical training. The presentation of the various considerations required and the theory pertaining to governor regulation is given mathematically in a large quantity of formulas. Some of this presentation could have been made more available to those designing engineers and students who have not had the rigorous mathematical training by graphical presentation so commonly used in engineering. The chapter on design covers a great many forms of governors little used in practice today, but which are considered by the author necessary to understand in order that the reader can more thoroughly appreciate the improvements made in later designs of governors. There is, however, a lack of information in reference to high speed shaft governors used in steam-turbine work.

A number of speed-regulating devices by auxiliary or indirect means are given, such as the use of oil or steam relay mechanisms between the governor proper and the regulating means of the prime mover. The various types shown pertain largely to German practice. It is regrettable that many excellent designs used in American practice are not presented because the achievements of American designers in auxiliary and indirect means of regulation have been marked.

To a student interested in the theory of governing of prime movers, this book cannot be neglected. It gives a careful presentation of all the fundamental problems encountered in the design of governors. The reader, however, must follow much of the subject from a rigorous mathematical point of view. The illustrations of the various governors are excellent. It would, however, have been valuable to have had some test data or experimental values derived from the actual performances of the newer governors described.

The influences of torsional oscillations of shafts upon governing of prime movers are more vital in problems dealing with reciprocating oil engines. These problems arise naturally in marine applications. Similar problems occur in very large steam turbines. The presentation as given in this book is most excellent and will give the reader the fundamental theory and formulas necessary for treating this problem.

Personals

S. I. Hess, formerly with the Public Service Electric Co., is now with the Southern California Edison Co.

Harry Pastre, of the Elliott Company, passed through New York last week on a start for a long trip through the South.

J. C. Long has opened offices in the Old South Building, Boston, Mass., as a power-plant consulting and betterment engineer. He is a member of the A.S.M.E. and has been for the last fifteen years chief plant engineer of the Boston Woven Hose and Rubber Company.

Irving E. Moultrop, well known to the readers of *Power* through his activities in the various engineering societies, started with the beginning of the present year his thirty-fourth year of service with the Edison Electric Illuminating Co. of Boston. Entering the employ of the company as chief draftsman, he rose inside of six years to the position of mechanical engineer, and in 1913 was made assistant superintendent of the construction bureau, and practically all of the stations of the company have been erected and

equipped under his direction and supervision.

T. C. Green, for many years with the Garlock Packing Co., has resigned to become general manager of the John F. Robertson Co., Pittsburgh, Pa., manufacturer of power-plant equipment. Tommy has a wide acquaintance among the engineers of the country through his popularity at conventions and, as secretary of the National Exhibitors' Association, has contributed largely to the success of recent exhibitions. Numerous friends will wish him an abundant success in his new connection.

Society Affairs

Coming Conventions

American Institute of Electrical Engineers — Spring Convention at Chicago, April 19-21. Headquarters, 29 West 39th St., New York City.

American Society of Mechanical Engineers — Spring Meeting at Atlanta, Ga., May 8-11. Secy., Calvin W. Rice, 29 West 39th St., New York City.

National Electric Light Association —Annual convention at Atlantic City, N. J., May 15-20. Headquarters, 29 West 39th St., New York City.

Atlanta Section, A. I. E. E. will meet March 30 for a talk on "Steam Turbines" by E. F. McLaughlin, of the G. E. Co.

Toronto Section, A. I. E. E., will meet April 7 to hear Prof. H. W. Price, of the University of Toronto, speak on "Power Factor."

Washington (D. C.) Section, A. S. M. E., will meet March 23 at Cosmos Club Hall to hear F. H. Rosencraft, of the Electric Bond and Share Co., speak on "A Steam-Electric Power Plant from Conception to Operation."

The American Chemical Society will hold its spring meeting April 3-7 at Birmingham, Ala., with headquarters in the Hotel Tutwiler. For information, see C. N. Wiley, Gulf States Portland Cement Company, Birmingham.

The Indiana Sanitary and Water Supply Association will hold its Fifteenth Annual Meeting March 22 and 23 at the Claypool Hotel, Indianapolis, Ind. The program will include a motion picture showing the manufacture of welded pipe, a paper on "Spontaneous Combustion," a discussion of waterworks building programs in Indiana, and many other features. The Secretary is C. K. Calvert, 1902 North Jersey St., Indianapolis.

Business Items

The Barto-Phillips Co., engineers and builders, have moved their offices from 280 Madison Ave. to 52 Vanderbilt Ave., New York City.

The Celite Products Co., manufacturer of high-temperature cement, etc., has established a district office at 79 Milk St., Boston, Mass. The company formerly distributed through Nightingale & Childs. F. H. Emerson will be in charge of the office.

Trade Catalogs

Cement-Gun Work—Cement-Gun Construction Co., 537 South Dearborn St., Chicago. An interesting booklet showing the many different applications of cement-gun work, including the lining of coal and ash bins, lining smokestacks, and building up new chimneys of concrete around old steel ones.

Fuel Prices

BITUMINOUS COAL

The following table shows the trend of the spot steam market in various coals (mine-run bases, f.o.b. mines):

Coal	Market Quoting	March 6, 1922	March 13, 1922
Pool 1,	New York	$3.00	$2.75@3.15
Pocahontas,	Columbus	1.85	1.75@2.00
Clearfield,	Boston	1.95	1.65@2.25
Somerset,	Boston	1.90	1.75@2.00
Pittsburgh,	Pittsburgh	2.15	2.10@2.20
Kanawha,	Columbus	1.60	1.50@1.75
Hocking,	Columbus	1.90	1.75@2.00
Pittsburgh No. 8	Cleveland	2.00	1.85@1.90
Franklin, Ill.,	Chicago	2.50	2.25@2.65
Central, Ill.,	Chicago	2.35	2.25@2.50
Ind. 4th Vein,	Chicago	2.50	2.35@2.50
Standard,	St. Louis	1.95	1.75@1.95
West Ky.,	Louisville	1.85	1.70@2.00
Big Seam,	Birmingham	1.85	1.70@2.00
S. E. Ky.,	Louisville	1.55	1.40@1.65

New York—On Mar. 16, Port Arthur light oil 22@25 deg. Baumé 4c. per gal. 30@35 deg., 5c. per gal., f.o.b. Bayonne, N. J.

Chicago—Mar. 8, for 24@28 deg. Baumé, 85@90c. per bbl.; 32@36 deg., 2⅜@2½c. per gal. in tank cars f.o.b. Oklahoma refinery, or freight adjusted.

Pittsburgh—On Mar. 14, f.o.b. refinery, Pennsylvania, 38@40 deg. 4¼c. Kentucky fuel oil, 26@30 deg., 3c. per gal. Western, 24@30 deg., 80c. per bbl.; 32@34 deg., 2¾c.; 36@38 deg., 3c.; 38@40 deg., 3¼c. per gal.

St. Louis—Mar. 11, prices f.o.b. cars, tank lots; 24@26 deg. Baumé, 90c. per bbl.; 26@28 deg., 95c.; 28@30 deg., $1.10; 32@34 deg., 2¾c. per gal.

Philadelphia—On Mar. 15, 26@28 deg. Baumé, Oklahoma, 85@90c. per bbl.; 30@34 deg., Oklahoma (group 3) 2½@3c. per gal.; 16@20 deg., Seaboard, $1@$1.10 per bbl.

Cincinnati—Feb. 27, for 26@30 deg. Baumé, 5c.; Diesel 32@34 deg., 5½c. per gal.; distillate 38@46 deg., 6c. per gal.

New Plant Construction

PROPOSED WORK

Cal., Fresno—R. F. Felchlin Co., Archt., Bank of Italy Bldg., is preparing plans for an 8 story office building on Tulare and J Sts. About $600,000. Owner's name withheld.

Cal., Los Angeles—A. E. Curlett, Archt., Merchants Natl. Bank Bldg., will soon receive bide for a 13 story, 85 x 165 ft. store and loft building including a steam heating system on 7th and Hill Sts. for the Sun Realty Co., care of Archts. About $500,000.

Cal., Richmond—The Galena Signal Oil Co., South Park and Liberty Sts., Franklin, Pa., has purchased a site and plans to build a refinery near the Standard Oil plant. About $500,000.

Cal., Santa Barbara—The Santa Barbara High School Dist. has been commissioned to prepare plans for high school buildings. About $500,000. W. H. Weeks, 369 Pine St., San Francisco, Archt.

Conn., New Britain—The Amer. Hosiery Co., Park St., is having plans prepared for a 1 story, 40 x 80 ft. boiler house at plant. About $25,000. Private plans.

Fla., Lakeland — The Southern College received low bid for three college buildings from Hugger Bros., Bell Bldg., Montgomery, Ala., $500,000. Noted Jan. 31.

Ia., Waterloo—The Roth Packing Co. plans to build an engine room and shipping station. About $150,000. Henschien & McLaren, 1637 Prairie Ave., Chicago, Ill., Archts.

Ill., Benton—Hays & Naumer Ice Co., Duquoin, is having plans prepared for a 2 story, 50 x 128 ft. ice plant. About $25,000. Kennerly & Stiegemeyer, Title Guaranty Bldg., St. Louis, Mo., Archts.

Ill., Chicago—A. S. Alschuler, Archt., 28 East Jackson Blvd., will soon receive bids for a 10 story, 100 x 125 ft. printer's bldg. including a steam heating system on Van Buren and Jefferson Sts. for J. T. Igoe Co., 117 West Harrison St. About $550,000.

Ill. Chicago—The Crawford Bldg. Corp., c/o C. H. Crane & K. Franzheim, Archts., 127 North Dearborn St., plans to build a 141 x 191 ft. theatre including a steam heating system on Roosevelt Rd. near Crawford Ave. About $1,000,000.

Ill., Chicago—G. F. Lovdall, Archt., 25 North Dearborn St., is receiving bids for a 3 story, 150 x 170 ft. hotel including a steam heating system on Wabash and 35th Sts. for Isidore, Rothchild & G. Schneider, care of architects. About $500,000.

Ill., Chicago—L. and E. F. Mayer, c/o Stratford Hotel, plans to build a 21 story, 171 x 180 ft. apartment or hotel, including a steam heating system on Michigan and Jackson Blvd. About $5,000,000. Marshall & Fox, 721 North Michigan Blvd., Archts.

Ill., Chicago—South Park Comrs., 57th St. and Cottage Grove Ave., will soon receive bids for a 45 x 60 ft. power plant on 45th St. and Marshfield Sts. About $32,000.

Ill., Joliet—A. Foster, Archt., 56 East Randolph St., Chicago, will receive bids about April 1 for a 3 story main building and a 4 story dormitory, etc., including a steam heating system at 303 Taylor St. for the St. Francis Academy. About $500,000.

Ill., Matteson—K. I. Herman, c/o Mid West Box Co., 111 West Washington St., Chicago, plans to build a 3 story, 60 x 140 ft. chemical plant including a steam heating system. About $300,000. H. C. Miller, 112 West Adams St., Chicago, Archt.

Ill., Oak Park—A. Eldridge, c/o Miuchin & Spitz Co., Archts., 19 West Jackson Blvd., Chicago, will soon receive bids for a 3 story, 150 x 175 ft. apartment including a steam heating system. About $275,000.

Ill., Peoria—W. W. Ahlschlager, Archt., 65 East Huron St., Chicago, will soon receive bids for a 10 story, 102 x 149 ft.

hotel on Adams and Liberty Sts. for P. Schnellbacher. About $1,000,000.

Ill., Wheaton—J. W. McCarthy, Archt., 139 North Clark St., Chicago, is receiving bids for a 3 story, 67 x 120 ft. school including a steam heating system for St. Michaelis Church. About $300,000.

Ind., Indianapolis—The Indianapolis Real Estate Bd., J. S. Cruse, Chn., 128 North Delaware St., plans to build a 22 story office building. About $1,000,000. Architect not selected.

Ind., Terre Haute—E. & A. Ehrmann, 9½ St., plans to build a 16 story office and mercantile building on 6th and Wabash Ave. About $500,000. Architect not selected.

Mass., Boston—The Park Square Real Estate Trust has had plans prepared for an 11 story, 75 x 600 ft. office bldg. on Arlington and St. James Sts. About $6,000,000. Densmore & Leclear, 88 Broad St., Archts.

Mass., Lawrence — The Amer. Woolen Co., 245 State St., Boston, is having plans prepared for a 6 story, 100 x 500 ft. mill bldg. at Washington Mills plant. About $800,000. Private plans.

Mass., Whitinsville—The Whitin Machine Wks. will soon award the contract for a 4 story, 95 x 300 ft. addition to machinery plant. About $300,000. J. D. Leland Co., 41 Mt. Vernon St., Boston, Archt.

Me., Belfast—The town has had plans prepared for a 3 story, 130 x 153 ft. high school. About $400,000. Kelham Hopkins & Greeley, 9 Park St., Boston, Mass., Archts.

Mo., Columbia—The University of Missouri, E. E. Brown, Business Mgr., will receive bids until April 10 for three buildings, agricultural, gymnasium and chemistry. Total cost about $475,000.

Md., Baltimore—H. Brady & Associates, 1006 North Calvert St., are having plans prepared for a 5 story apartment. About $800,000. Milburn, Heister & Co., 710 14th St., Washington, D. C., Archts.

Md., Baltimore—The Johns Hopkins Hospital, Monument and Wolfe Sts., is having plans prepared for an 8 story school of hygiene. About $1,000,000. Archer & Allen, 1 East Lexington St., Archts.

Md., Baltimore—I. Silberstein, Equitable Bldg., is having preliminary plans prepared for an 11 story, 48 x 144 ft. hotel on Paca and Fayette Sts. About $600,000. Architect not announced.

Minn., Minneapolis—The Ambassador Holding Co., 630 McKnight Bldg., is having plans prepared for a 3 story, 112 x 192 ft. apartment including a steam heating system on 19th St. and 2nd Ave. About $300,000. O. K. Westphal, 309 Kasota Bldg., Archt.

Minn., Minneapolis—The Northwestern Natl. Life Insurance Co., J. T. Baxter, Pres., 11th St. and Nicollet Ave., plans to build a 3 or 4 story office building on 15th and Oak Grove Sts. About $300,000. Architect not selected.

Mo., St. Joseph—The Bd. Public Wks., c/o G. E. Jackson, Clk., plans to build a 3 story museum including a steam heating system. About $390,000. W. K. Seitz, City Hall, Engr.

Mo., St. Louis—The Famous-Barr Dry Goods Co., M. T. May, Pres., 6th and Oliver Sts., plans to build a 6 story garage including a steam heating system on 7th and Elm Sts. About $400,000. W. Levy, 625 Locust St., Archt.

Neb., Culbertson—The city plans to install additional motor and pump and extend mains about 4,000 ft. About $15,000. Hershey & Merick, Brownell Blk., Lincoln, Engrs.

Neb., Lincoln—The city, T. Berg, Clk., will receive bids until April 1 for pipe valves and fittings for cooling pond equipment, also steam and water lines to be installed in power house. About $20,000. G. Bates, Engr.

N. J., Atlantic City — F. A. Berry, Archt., Real Estate Trust Bldg., Phila., will soon receive bids for a 4 story, 60 x 106 ft. home for girls including a steam heating plant on Pennsylvania Ave. for the Stella Marvis Catholic Daughters of Amer., c/o Dr. Sherman, Pennsylvania and Pacific Aves.

N. J., East Orange—J. Bursteiner, c/o D. M. Ash, Archt., 1 Madison Ave., New York City, will soon award the contract for a 7 story apartment on Harrison Ave. About $500,000. Noted Feb. 14.

N. J., Scudder Falls (Welburtha P. O.)—The Bd. Educ., State House, will receive bids until March 28 for school for deaf, including a pump house, boiler house, etc. About $350,000. A. H. Moses, 136 South 4th St., Phila., Archt. Guilbert & Betelle, 12th and Lombardi St., Newark, Engr.

N. Y., Batario—The city plans to vote $450,000 bond issue April 6 for a 3 story, 144 x 200 ft. high school on Ross St. E. E. Joralemon, 482 Delaware Ave., Buffalo, Archts.

N. Y., Binghamton—The Tioughnioga Oil, Gas & Mineral Co., 97 Water St., is in the market for a 35 to 50 hp. mounted boiler.

N. Y., Brooklyn—The Brooklyn Retail Butcher's Corp. plans to build a 4 or 5 story cold storage building. About $200,000. Henschien & McLaren, 1637 South Prairie St., Chicago, Ill., Archts.

N. Y., Brooklyn—The Brooklyn State Hospital for Insane, Clarkson Ave., is having sketches made for additions to hospital. About $3,000,000. L. F. Pilcher, Capitol, Albany, Archt. and Engr.

N. Y., Brooklyn — The Church of the Sacred Heart of Jesus and Mary, Rev. Bishop T. C. Malloy, 500 Hicks St., will soon receive bids for a 4 story parochial school on Hicks St. About $300,000. N. Serracino, 507 5th Ave., New York City, Archt. and Engr.

N. Y., Buffalo—The Sparks Dairy Co., 146 Prospect St., is in the market for a 20 or 30 hp. return tube boiler.

N. Y., Elmira — Pierce & Bickford, Archts., 118 Lake St., plans a 2 story, 161 x 230 ft. high school. About $550,000. A. R. Acheson, Eikel Theater Bldg., Syracuse, Engr.

N. Y., Furniss (Oswego P. O.)—The Oswego Gardens Inc., plan to build a cold storage plant here. About $30,000, will install refrigerating plant, capacity 11,000 bbls. Address P. T. Vercrouse, Oswego.

N. Y., Ithaca—The Bd. of Trustees, Cornell University, have approved plans and will soon receive bids for a central heating plant to be located north of the East Ithaca Station. About $750,000. H. R. Kent, Engr. Corp., 5 Erie Ave., Rutherford, N. J., Engr.

N. Y., Newburgh—D. C. Miller, 258 Bway., is in the market for an 80 to 100 hp. locomotive, Marine type boiler, guaranteed for at least 110 lbs. working pressure, prefer seams butt and double strapped.

N. Y., New York—The Bd. Purchase, Municipal Bldg., will receive bids until March 23 for furnishing and delivering alternating current machinery and equipment for trackless trolley system and equipment for a 300 kw. automatic substation for trackless trolley system.

N. Y., New York—Schwartz & Gross, Archts., 347 5th Ave., are preparing plans for a 15 story, 200 x 200 ft. apartment hotel on Madison Ave. About $5,000,000. Owner's name withheld.

N. Y., Portchester—M. Di Leo, Westchester Ave., is receiving bids for an 80 x 130 ft. 300 ton coal bunker. Conveying machinery will be required. About $25,000. F. Urso, 453 West Main St., Engr. Noted March 14.

N. C., Asheville — Williams-Brownell Planing Mill Co., Inc., J. P. Manson, Purch. Agt., is in the market for two tubular boilers 100 hp., used if practically new and capable of carrying 125 to 150 steam pressure for re-installation.

N. C., Lexington — The Bd. of Town Comrs., A. Leonard, Mayor, Town Hall, will receive bids until April 6 for improvements to waterworks including pumping station, filter houses, filter tube, auxiliary station, coagulating basin, storage reservoir, 3½ mi. pipe line, 3½ mi. 2,200 volt transmission line, motor driven centrifugal pumps, filter plant equipment, etc. P. R. Raper, Clk., G. C. White Co., Durham, Engrs.

N. C., Raleigh—The Capitol Constr. Co., Inc., c/o J. Daniels, 801 Newbern Ave., plans to build a hotel. About $1,000,000. Architect not selected.

N. C., Winston Salem—C. B. Keen, Archt., Bailey Bldg., Phila., Pa., will soon receive bids for a 1 story, 100 x 200 ft. auditorium for J. E. Johnson, Winston Salem. About $400,000.

N. D., Devils Lake—The Bd. Educ., A. E. Pearshall, Clk., is having plans prepared for a 2 story high school including a steam heating system. About $300,000. J. B. DeRemer, Grand Forks, Archt.

N. D., Grand Forks—The Red River Power Co., W. H. Brown, Mgr., 27 South 3rd St., plans improvements to electric light plant, including installation of a 2,000 kw. turbine and laying 20 in. pipe line from plant to Red River. About $125,000.

O., Cleveland—The Bd. County Comrs., has had plans prepared for a high pressure pumping station and cast iron water mains in Chestnut Hill dist. State Rd. About $45,000. R. F. MacDowell, Court House, Engr.

O., Cleveland—The Cleveland Maternity Hospital, c/o A. Garfield, Archt., Natl. City Bldg., is having preliminary plans prepared for a 6 story, 60 x 157 ft. maternity hospital at 11020 Euclid Ave. About $350,000.

O., Cleveland—T. Horobin, 2850 Eaton Rd., will receive bids about March 28 for a 4 story, 206 x 258 ft. apartment on Shaker Blvd. and East 128th St. About $350,000. H. P. Whitworth, 526 Hickox Bldg., Archt. Noted Aug. 23.

O., Cleveland—The Ward Baking Co., c/o J. B. Arthur, East 143rd St. and Southern Blvd., New York City, will soon award the contract for a 3 and 5 story, 240 x 315 ft. bakery plant and office building on East 45th Place and Windsor Ave. About $500,000. C. B. Comstock, 110 West 40th St., New York City, Archt. Noted Feb. 21.

O., Columbus—The Columbus Apartment Co., B. Reinmund, 1260 East Main St., is having plans prepared for a 12 story apartment, about $1,100,000, and a 7 story apartment, about $900,000, both on East Broad St. J. Denson, 5 North LaSalle St., and R. F. France, 155 North Clark St., Archts.

O., Conneaut—The School Bd. has purchased a site and plans to build a high school. About $500,000.

O., Germantown—The city is having plans prepared for waterworks improvements, including about 65,000 ft. new lines, 4 to 12 in. About $100,000. Deep well system, pumping station, etc., will be figured later. Jennings, Lawrence Co., Hartman Bldg., Columbus, Engr.

O., Salem—The Purity Milling Co. is in the market for a gas or oil engine, 25-50 hp.

O., Toledo—The Sandusky Cement Co., c/o F. G. Herman, Engineers Bldg., Cleveland, plans to build a 1 story cement plant twelve miles west of here. About $1,000,000. W. B. Rawson, Engineers Bldg., Cleveland, Archt.

Pa., Ebensburg—The borough, J. B. Lehman, Boro. Secy., will receive bids until March 30 for the construction of a reservoir and pumping station to include cast iron pipe, two pumps, capacity 550 gal. per min., head 285 ft. J. L. Elder, Engr.

Pa., Erie—The Bd. Educ., Library Bldg., plans to build a 2 story, 270 x 660 ft. junior high school on 23rd and Cascade Sts. About $350,000. W. W. Meyers, Library Bldg., Archt.

Pa., Erie—The Diocese of Erie, c/o J. M. Gammon, 205 West 9th St., is having sketches made for an orphanage on Kakwa Annex, About $500,000. Architect not selected.

Pa., Kane — The Keystone Power Co. plans two new units to power plant. Company open for quotations on new units.

Pa., Overbrook—Madames of the Sacred Heart, 19th and Arch Sts., are having plans prepared for a 3 story, 200 x 280 ft. academy on City Line and Haverford Ave. About $750,000. P. Monaghan, 1218 Chestnut St., Phila., Archt.

Pa., Phila.—L. Cahan, St. James Hotel, 13th and Walnut Sts., plans to build a 15 story office bldg. on Walnut and Juniper Sts. About $1,000,000. Architect not selected.

Pa., Phila.—The city will soon award the contract for a 3 story, 105 x 147 ft., 2 story, 93 x 38 ft., with 2 wings, 37 x 88 ft., residence for internes, including a steam heating plant on 34th and Pine Sts. About $500,000. P. H. Johnson, Presser Bldg., Archt.

Pa., Phila.—Lippencott & Young, Archts., 10 South 18th St., will receive bids until April 1 for a 7 story, 130 x 130 ft. hotel. About $500,000. Owner's name withheld.

Pa., Phila.—The Rodgers Hosiery Co., Lena and Collom Sts., is having plans prepared for a 3 story, 154 x 174 ft. hosiery mill on Stenton and Wyoming Aves. About $300,000. Private plans.

Pa., Phila. — A. Shapiro Land Title Bldg., plans to build a 4 story, 115 x 250 ft. apartment on 47th and Walnut Sts. About $500,000. Architect not selected.

Pa., Phila.—The Sun Oil Co., c/o J. M. Pier, Jr., Finance Bldg., has had plans prepared for a 12 story, 36 x 84 x 88 ft. office bldg. on 17th and Cherry Sts. About $500,000. H. Trumbauer, Land Title Bldg., Archt.

Pa., Phila.—J. B. Van Sciver Co., Market St. Ferry, Camden, N. J., will soon award the contract for a 7 story warehouse and factory building on Arch St. and Delaware Ave. About $600,000. Ballinger Co., 12th and Chestnut Sts., Archts.

Pa., Pittsburgh—F. Brown, 565 5th Ave., New York City, is having preliminary sketches made for converting residence into apartment hotel and building two 4 story additions on North Highland and Jackson Sts. About $1,000,000. Kennedy Ellington Assoc., 230 5th Ave., Archts.

S. D., Watertown — The Pub. Utilities Comn., G. K. Burt, Secy., will receive bids until March 30 for two motor driven pumping units, about 500 and 750 gal. per min. cap.

Tenn., Nashville—G. Norton, Archt., 1119 Independent Life Bldg., will receive bids until March 27 for a 3 story, 140 x 160 ft. office bldg. on 7th and Union Sts. for the Natl. Life & Accident Co., 7th Ave. About $1,000,000. Separate contract for mechanical equipment.

Va., Danville—The city is receiving bids for installing a 2,500 kw. turbine generator, switchboards and accessories, also two 400 hp. boilers. Scofield Engr. Co., Commercial Trust Bldg., Phila., Pa., Engr.

W. Va., Crafton—The city plans to vote $100,000 bond issue March 28 for extending waterworks and construction of filtration plant.

W. Va., Morgantown — P. Davis, 3rd. Archt., 1713 Sansom St., Phila., Pa., will soon receive bids for a 3 story, 120 x 200 ft. gymnasium, including a steam heating system on Fraternity Row for the University of Wisconsin. About $750,000. Noted Nov. 15.

W. Va., Wheeling—The city plans to vote a bond issue of $2,000,000 for a sand filtration system, improvements to water works, new mains, etc. M. Knowles, Jones Law Bldg., Pittsburgh, Pa., Engr.

Wis., Janesville — The Bd. Educ., City Hall, is having plans prepared for the installation of a hot water or steam heating system. C. O. Kerch, City Hall, Engr.

Wis., Milwaukee — M. A. Weinreis, 241 Lake St. is in the market for three air compressors, one 300 to 350 ft. two stage belt driven; one 8 x 8 x 8 belt driven, and one 10 x 10 belt driven.

Wis., Peshtigo—The Oconto Service Co., T. Pamferer, Pres., will receive bids until March 28 for a dam about 200 ft. of which is in 4-8 ft. of water, 2 steel gates, generator and switchboard. Mead & Seaston, State Journal Blk., Madison, Engrs. Noted Feb. 14.

Ont., Ottawa—W. E. Noffke, Archt., 46 Elgin St., will receive bids about April 1 for a 5 story, 66 x 99 ft. hotel on Sparks St. for G. Davidson, Wellington St. About $330,000.

Ont., Ottawa—The Ottawa Hydro Electric Comn., J. E. Brown, Genl. Mgr., 109 Bank St., will receive bids until March 24 for electrical supplies including meters, transformers, wire, etc.

Ont., Woodbridge—The town is having plans prepared for a waterworks system to include pumps, mains, water tank, hydraulic valves, etc. About $40,000. James, Proctor & Redfern, 36 Toronto St., Toronto, Engrs.

Que., Quebec — The Provincial Government plans to construct dams to conserve the waters and regulate the flow of River Ouareau in the Laurentian Mts. beyond St. Agathe. About $250,000. E. Vallee, Parliament Blags., Ch. Engr.

Australia, Melbourne—State Electricity Comn., of Victoria, R. Liddelow, Secy., 673 Bourke St., will receive bids until April 29 for supply, delivery, etc., Spec. 200, 22,000 volt, 3 core cable and accessories. Copies of tender form and specification will be available upon application to office of the Bureau of Foreign & Domestic Commerce, U. S. Dept. of Commerce, 1st Natl. Bank Bldg., Chicago, Ill., and office of the Bureau of Foreign & Domestic Commerce, U. S. Dept. of Commerce, 734 Customs House, New York City.

CONTRACTS AWARDED

Cal., Eureka — The Bd. Supervisors, Humboldt County, has awarded the contract for a laundry and heating plant for the Tubercular County Hospital to Mercer-Fraser Co., Eureka, $9,994. Noted Jan. 3.

Cal., Los Angeles—W. W. Paden, 605 Story Bldg., has awarded the contract for a 12 story, 50 x 155 ft. office bldg. on 8th and Spring Sts. to the Clinton Constr. Co., 140 Townsend St., San Francisco. About $331,755. Steam heating system will be installed. Noted March 7.

Cal., Sacramento—W. C. Phillips Co., c/o Union Ice Co., 9th and C Sts., has awarded the contract for a 1 story artificial ice plant near Western Pacific shops to D. R. Wagner, Call Bldg., San Francisco. About $16,000.

Cal., San Francisco—A. C. Blumenthal, 58 Sutter St., has awarded the contract for an 8 story apartment on Jackson and Laguna Sts. to MacDonald & Kahn, 130 Montgomery St., $500,000.

Fla., Gainesville—The city, G. H. Cairn, City Mgr., has awarded the contract for an addition to electric power plant including 625 kva. turbo generator to the Westinghouse Electric & Mfg. Co., Union Bldg., Pittsburgh, Pa. About $30,000. Noted Feb. 28.

Ia., Davenport—The Duck Creek Dist. 11 has awarded the contract for a sewerage system and pumping station including 11,316 ft. of 24-42 in. sewer pipe to Matthes Coal & Constr. Co., 1810 Bowditch St., $163,000. Noted Feb. 14.

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Ill., Evanston—The Boyle Ice Co., 847 Larrabee St., Chicago, has awarded the contract for a 2 story, ice manufacturing plant at 542 Linden Ave., here, to A. C. Thielberg, 154 West Randolph St., Chicago. About $40,000.

Ill., Jacksonville—The state will build a 1 story, 40 x 100 ft. and 90 x 131 ft. ward bldg. About $300,000. Owner will build by day labor. Steam heating system will be installed.

Kan., Sabetha—The city has awarded the contract for pipe line, developing springs also pumping equipment to Asplund Constr. Co., Tecumseh, Nebr., $12,371.08. Noted Jan. 17.

Mass., Dorchester (Boston P. O.)—The Meisel Press, Dorchester Ave., Boston, has awarded the contract for a 1 and 2 story, 40 x 80 ft. and 161 x 302 ft. machine shop on Locust St. to the Tredennick Co., 10 High St., Boston. About $250,000.

Mich., Detroit — The Detroit Mortgage Corp., Real Estate Exchange Bldg., has awarded the contract for a 6 story, 67 x 150 ft. apartment on John R. St. to Bryant & Detwiler, 2331 Dime Bank Bldg. About $510,000. Contract for steam heating will be awarded later. Noted Jan. 10.

N. Mex., Albuquerque—The Albuquerque Hotel Co. has awarded the contract for a 7 story, 120 x 140 ft. hotel on Central Ave. to J. J. Garfield, Tucson, Ariz. $300,000. A vacuum steam heating system will be installed.

N. Mex., Albuquerque—The First Natl. Bank has awarded the contract for an 8 story, 120 x 140 ft. bank and office bldg. on Central Ave. to Sumner Sollitt Co., 416 Trust Bldg., El Paso, $450,000. A vacuum steam heating system will be installed.

N. Y., Brooklyn — The Bd. Educ., 500 Park Ave., has awarded the contract for an addition to P. S. No. 67 on St. Edwards St., to Frymier & Hanna, 25 West 45th St., New York City, $424,000.

N. Y., Lackawana—The Assoc. of our Blessed Lady of Victory, c/o Rt. Rev. N. H. Baker, will build a 2 story shrine bldg. on South Park Ave. About $1,000,000. Owner will build by day labor.

N. Y., New Brighton (Staten Island P. O.)—The Bd. Educ., 500 Park Ave., New York City, has awarded the contract for a heating and ventilating system in Curtis H. S. to D. J. Rice, 405 Lexington Ave., New York City, $58,480. Noted March 7.

N. Y., New York—Bd. Water Supply, Gas and Electricity, Municipal Bldg., has awarded the contract for furnishing and installing electric operating equipment for the 48 in. valves at the 86th St. and 135th St. gatehouse to the Crocker Natl. Fire Prevention Engr. Co., 22 West 30th St., $28,825.

N. Y., New York—The Carnival Palace Corp., c/o W. K. McElfatrick, 701 7th Ave., will build a 1 story amusement palace on Academy St. near Bway. About $450,000. Work will be done by separate contracts under supervision of the architect.

N. Y., New York—The city has awarded the contract for sewerage treatment plant, two pumping stations, including the necessary equipment and machinery to the Riverdale Constr. Co., 1440 Bway., $349,754.

N. Y., New York—Jatison Constr. Co., Inc., 280 Madison Ave., will build a 15 story stores and office bldg. at 142 West 36th St. Owner will build by day labor.

N. Y., St. George (Staten Island P. O.)—The Pentz Realty & Constr. Co., c/o Litchfield & Rogers, Archts., 477 5th Ave., New York City, will build a 6 story apartment, including a steam heating system, on Central Ave., near Bay St. About $350,000. Work will be done by separate contracts.

N. Y., Watertown—The Northern New York Utilities, Inc., 58 Pub. Sq., has awarded the contract for foundation for dam and power plant at Browns Falls to the Burns Engr. Co., Bank Bldg. About $90,000.

O., Middletown — The Bd. Educ. has awarded the contract for a high school and grade school to the Willing Bros. Co., Bellevue. Cost $622,000.

Pa., Phila.—W. and S. Dyer, Engr., Land Title Bldg., has awarded the contract for a textile factory to consist of various buildings on Wyoming Ave. and G St. to H. E. Baton, 1713 Sansom St. About $500,000. A steam heating system will be installed.

Pa., Phila.—The Ocean Nebel Knitting Mills, 3860 Coral St., has awarded the contract for a 1 story, 52 x 59 ft. boiler house, stack and tank on 5th and Annsburry St. to H. P. Schneider, 3713 Old York Rd., $75,000.

Pa., Phila.—The Quaker City Cold Storage Co., 301 Delaware Ave., will build a 1 story, 27 x 126 ft. ice plant on Delaware Ave. Total cost including equipment, $75,000. Owner will build by day labor.

Pa., Phila.—The Stanley Co., c/o J. E. Mastbourne, 1214 Market St., has awarded the contract for a 10 story theatre and office building on 11th and Market Sts. to Hoffman-Henon Co., Finance Bldg. Total cost about $3,000,000.

Ont., Gravenhurst — The Muskoka Free Hospital for Consumptives, 223 College St., Toronto has awarded the general contract for a 3 story hospital to Jackson Lewis Constr. Co., Ryrie Bldg., Toronto. Total cost about $450,000. Noted April 5.